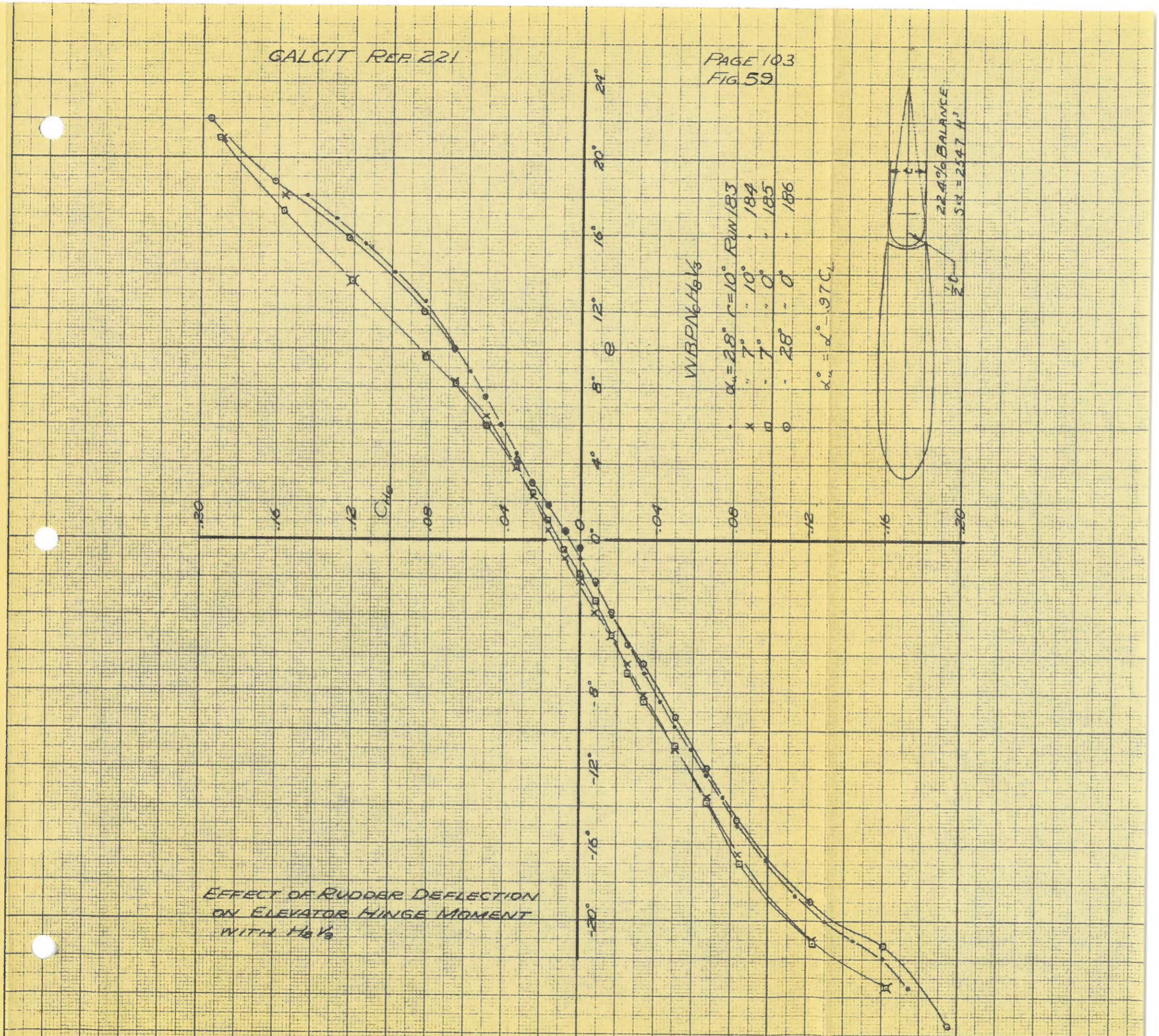
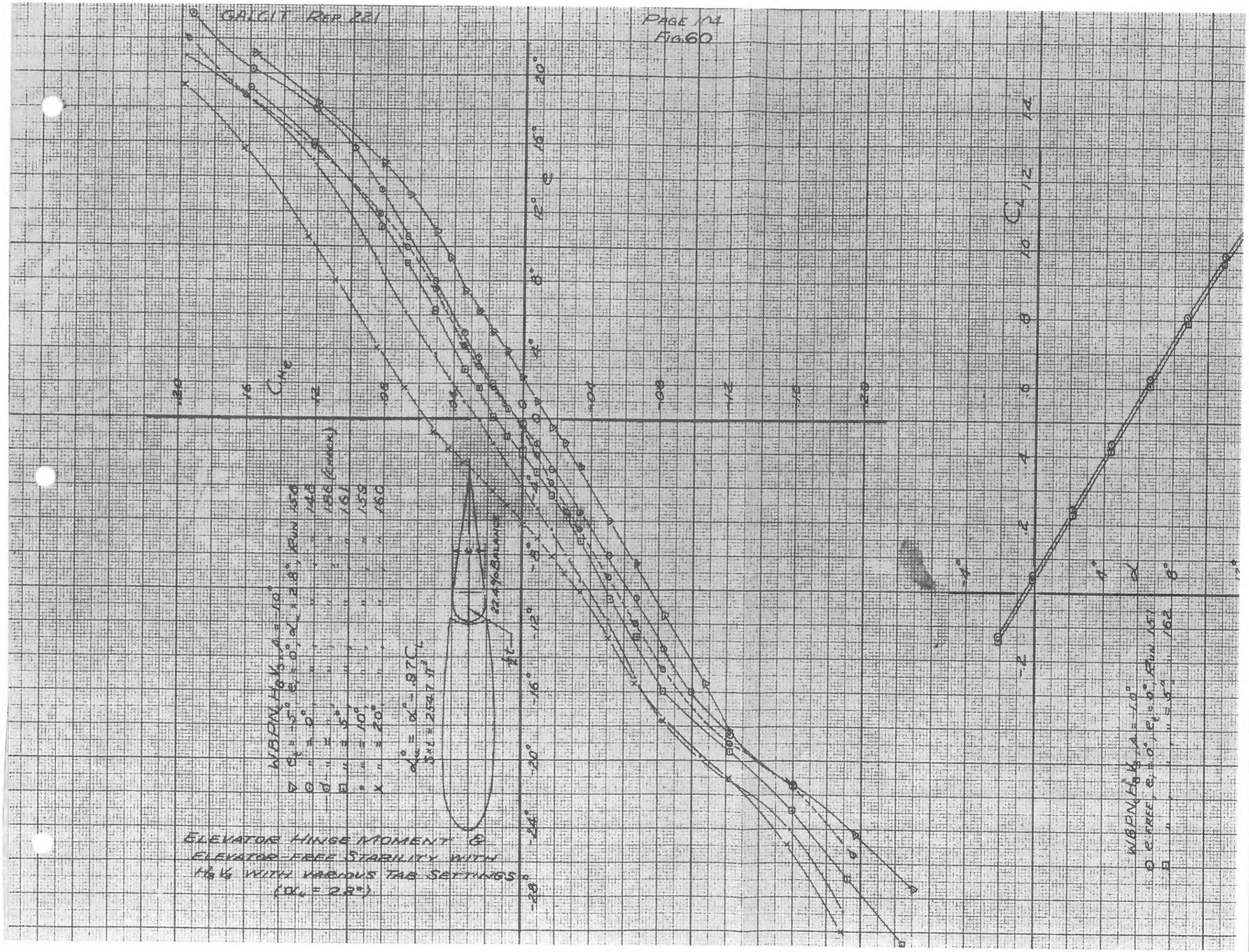
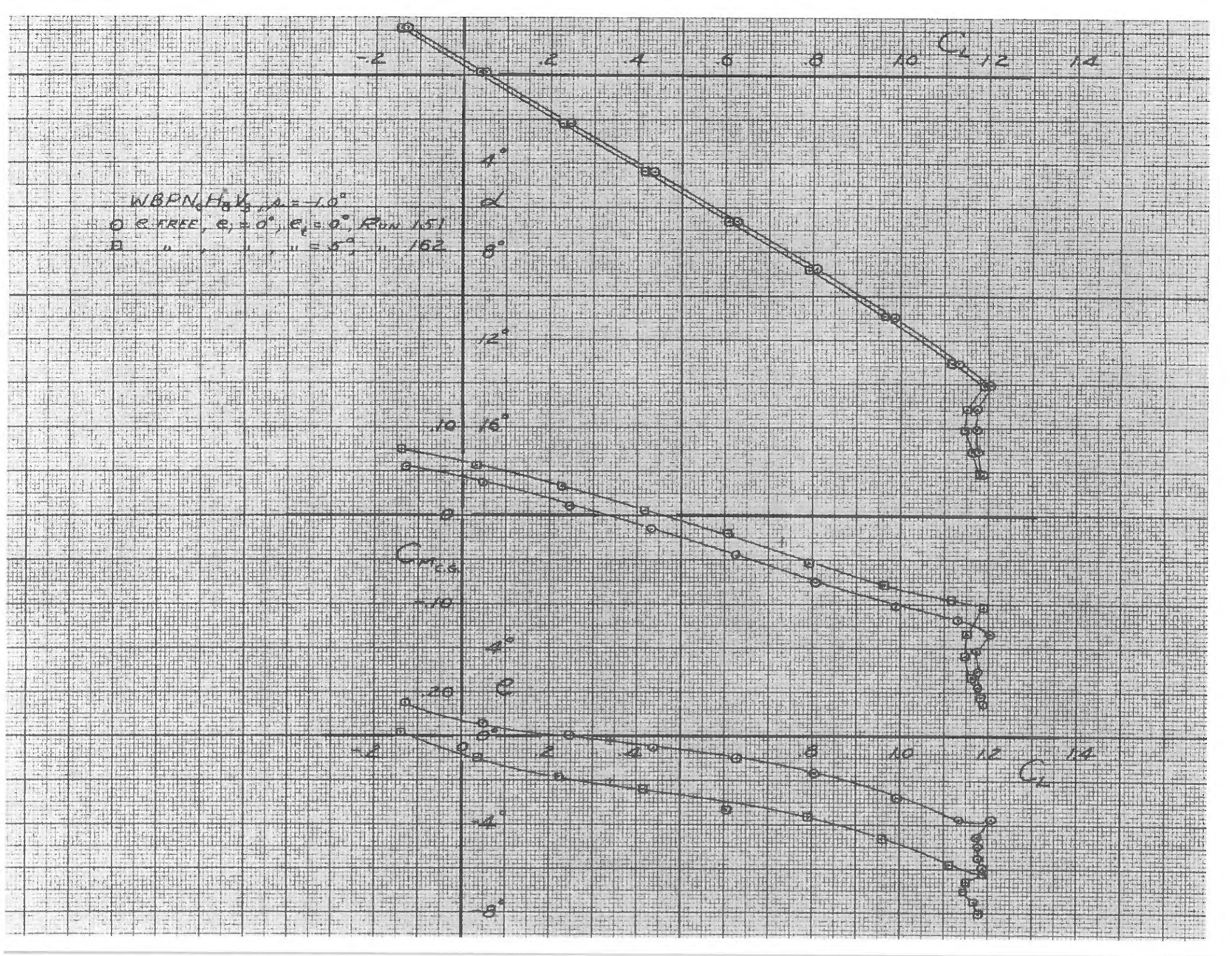
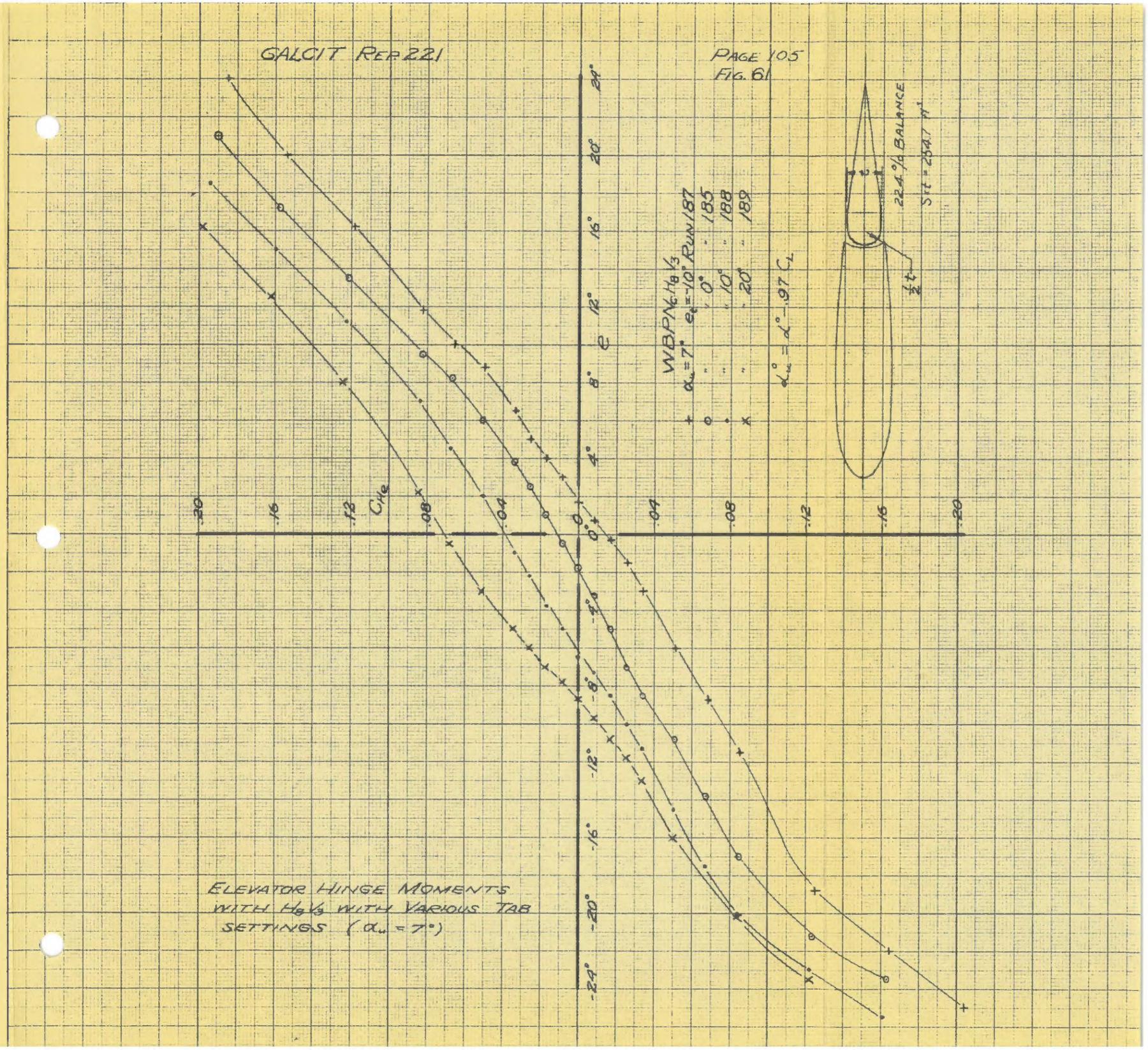


EFFECT OF RUDDER DEFLECTION ON ELEVATOR HINGE MOMENT WITH H_6V_3

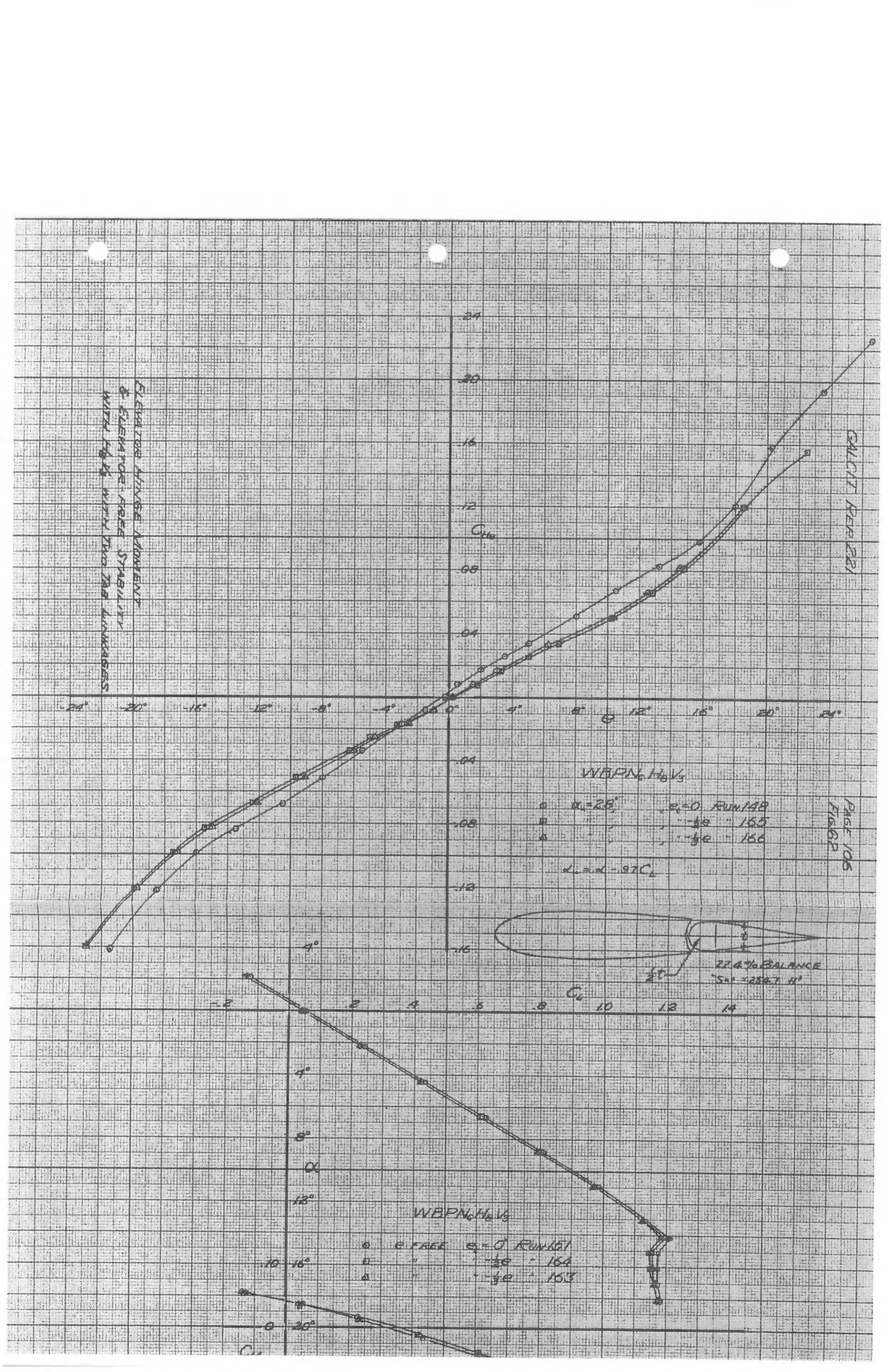


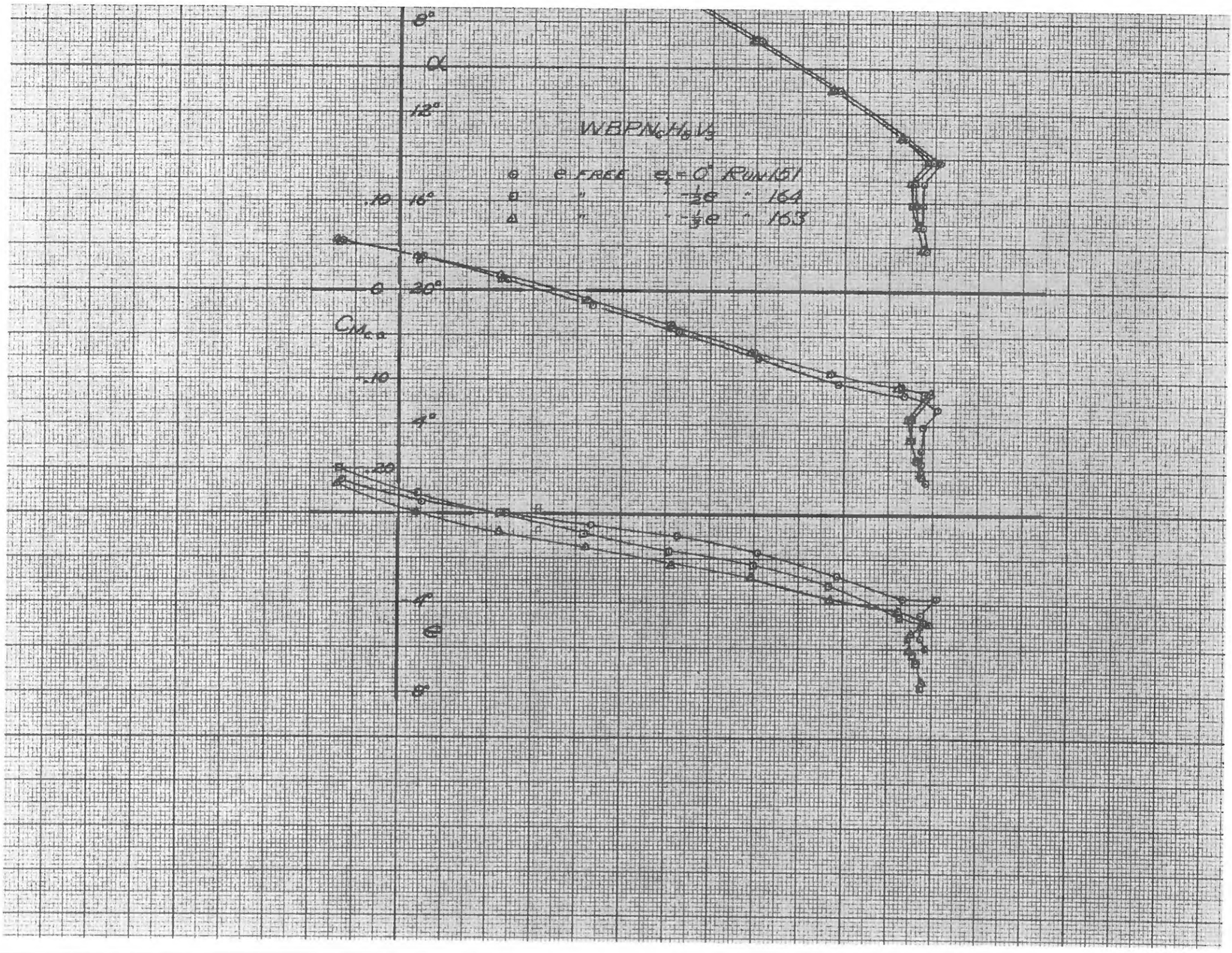
Elevator Hinge Moment & Elevator Free Stability with $H_e H_t$ with various tab settings. ($\alpha_t = 2.8°$).

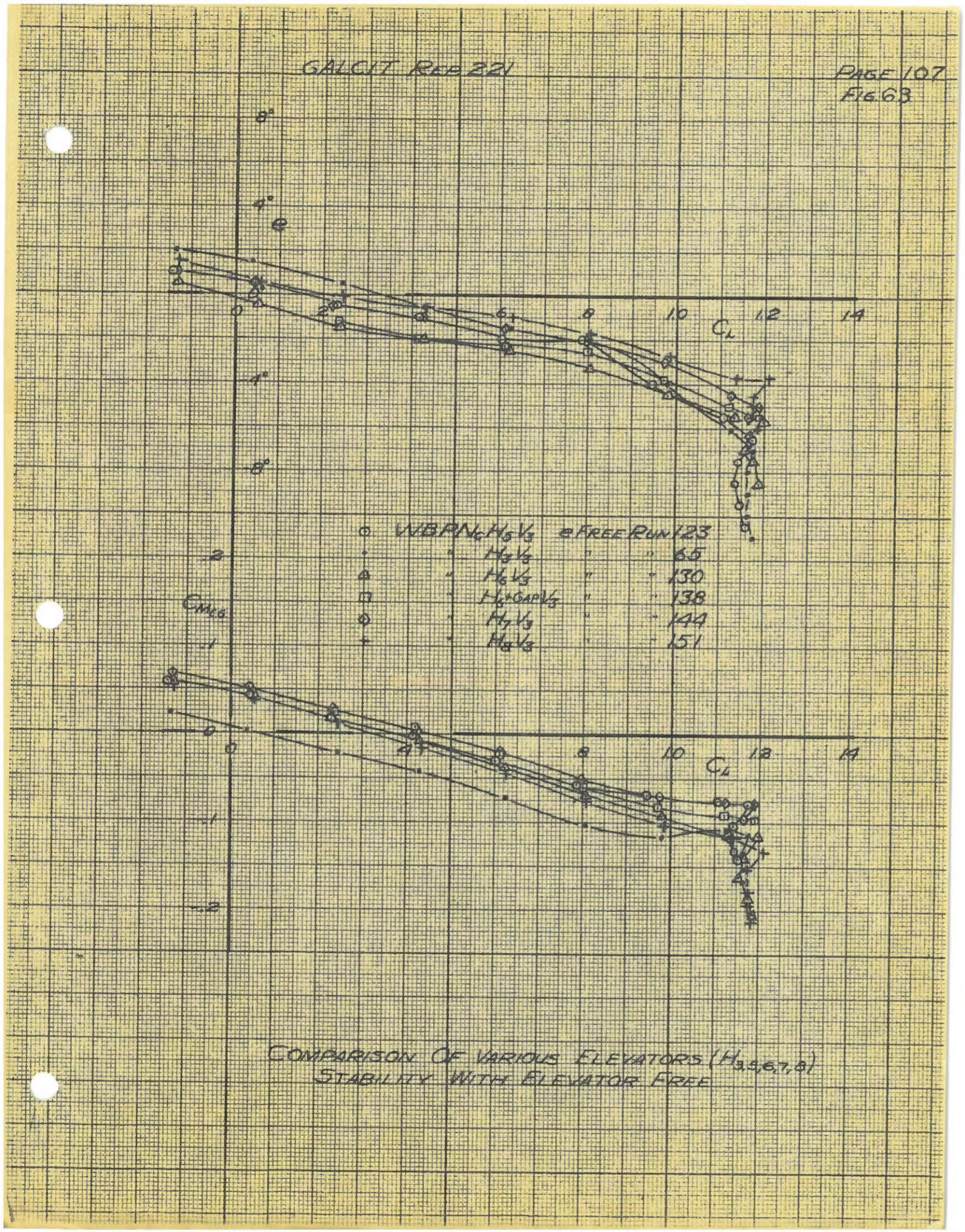

WBPN6 H6 V3 , i_t = -1.0°
○ ⊕ FREE, e_1 = 0°, e_t = 0°, R_DM 151
□ " " " " " = 5° " 162
C_L
C_m c.g.
α
-2
2
4
6
8
10
12
14
-4°
0
4°
8°
12°
16°
20°
.10
-.10



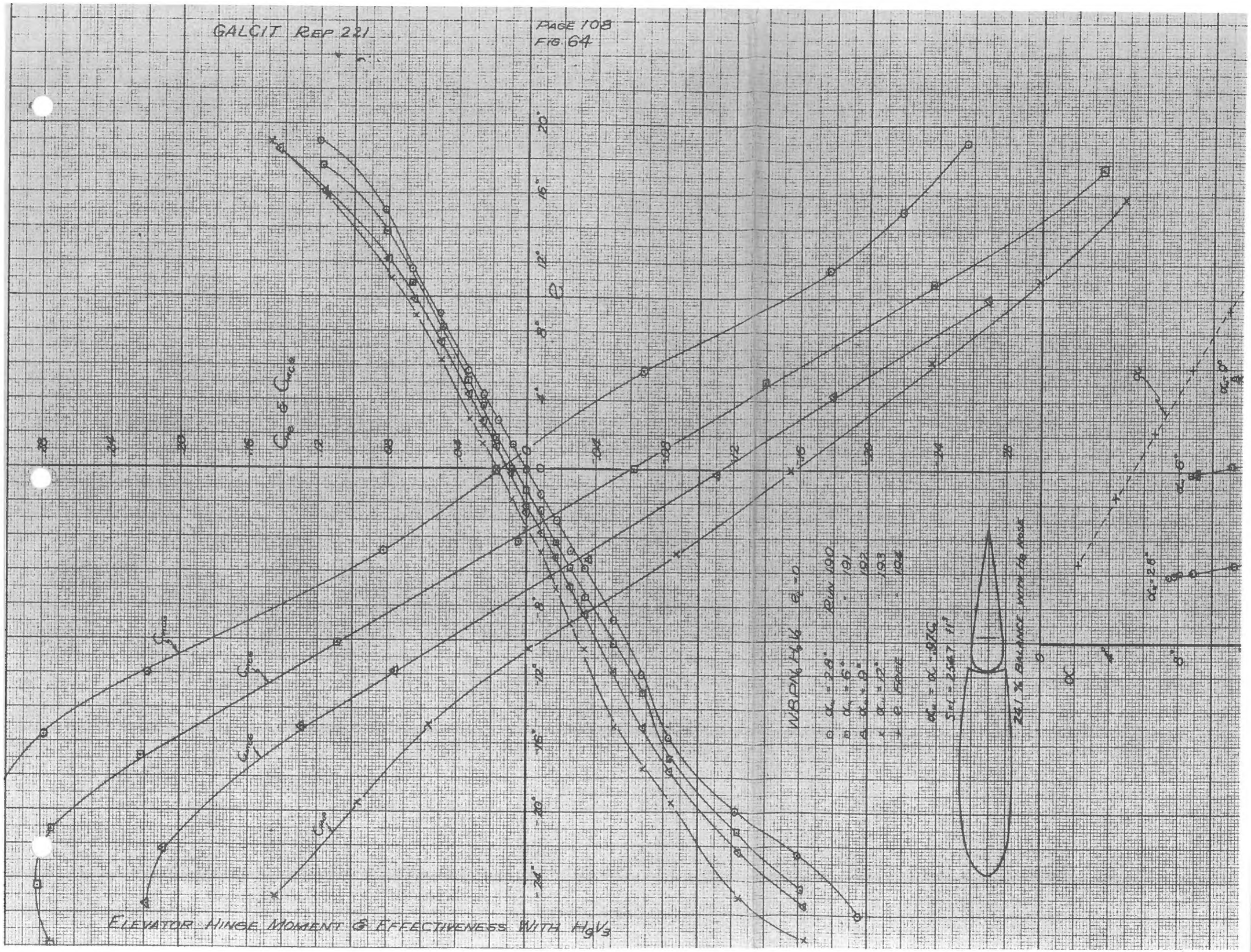
ELEVATOR HINGE MOMENTS WITH HB 1/3 WITH VARIOUS TAB SETTINGS ($\alpha_w = 7°$)


ELEVATOR HINGE MOMENT & ELEVATOR FREE STABILITY WITH $\frac{1}{2}\theta$ WITH TWO TAB LINKAGES
CALCIT REP 1221
PAGE 106 FIG 62
C_{H_e}
α
$WBPN_6H_6V_3$
$\alpha_t = 28°$ $\epsilon_t = 0$ RUN 148
" " " $-\frac{1}{2}\theta$ " 165
" " " $-\frac{1}{3}\theta$ " 166
$\alpha_t = \alpha - .97C_L$
22.4% BALANCE
$S_H = 284.7$ SF
C_L
$WBPN_6H_6V_3$
ϵ FREE $\epsilon_t = 0°$ RUN 151
" " $-\frac{1}{2}\epsilon$ 164
" " $-\frac{1}{3}\epsilon$ 163
C_M

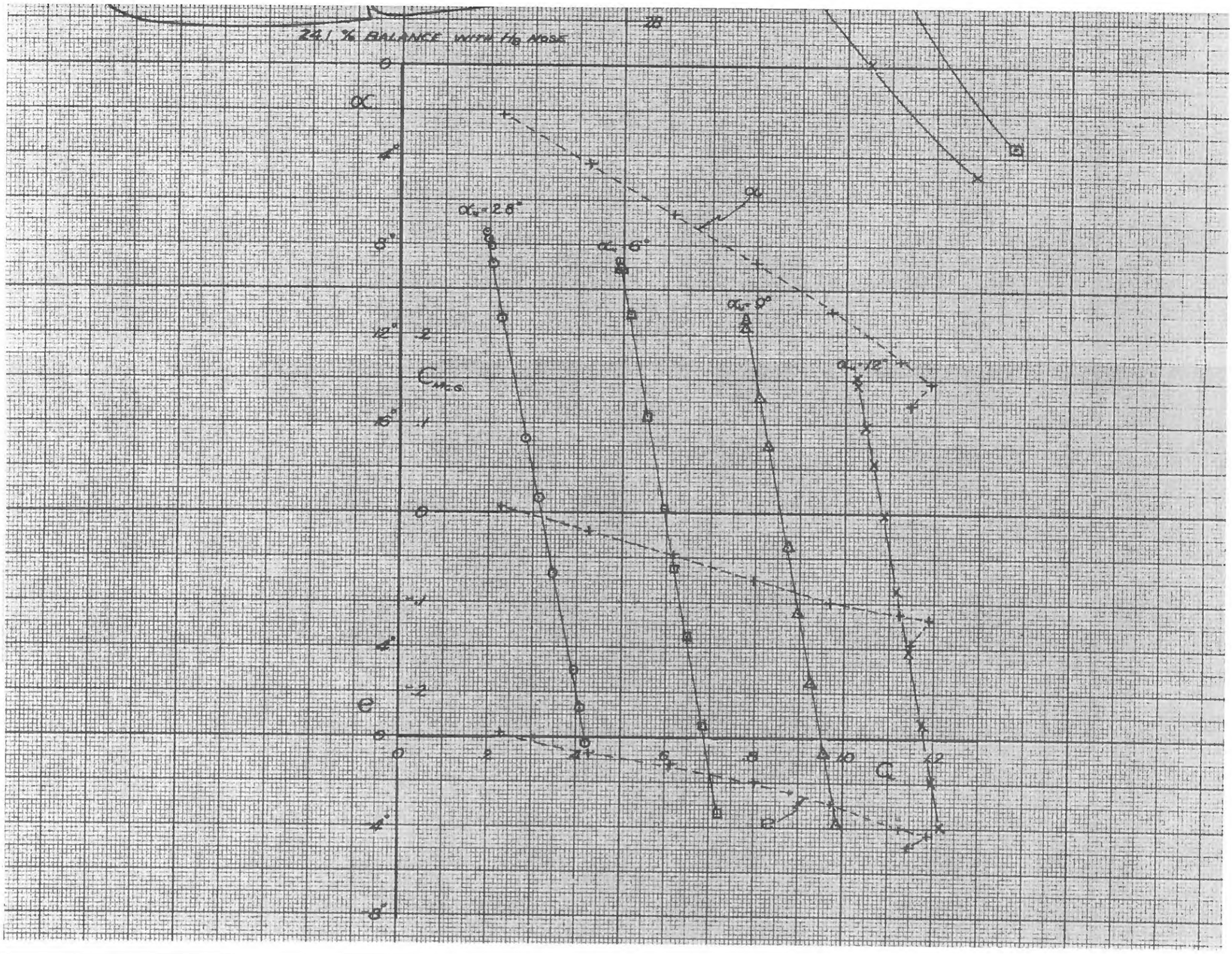

8°
α
12°
WBPN6H6 V3
e FREE e_t = 0° RUN 161
" " = -1/2 e = 164
" " = -1/3 e = 163
16°
10
0
20°
C_Mc.a
-10
4°
-20
4°
e
8°

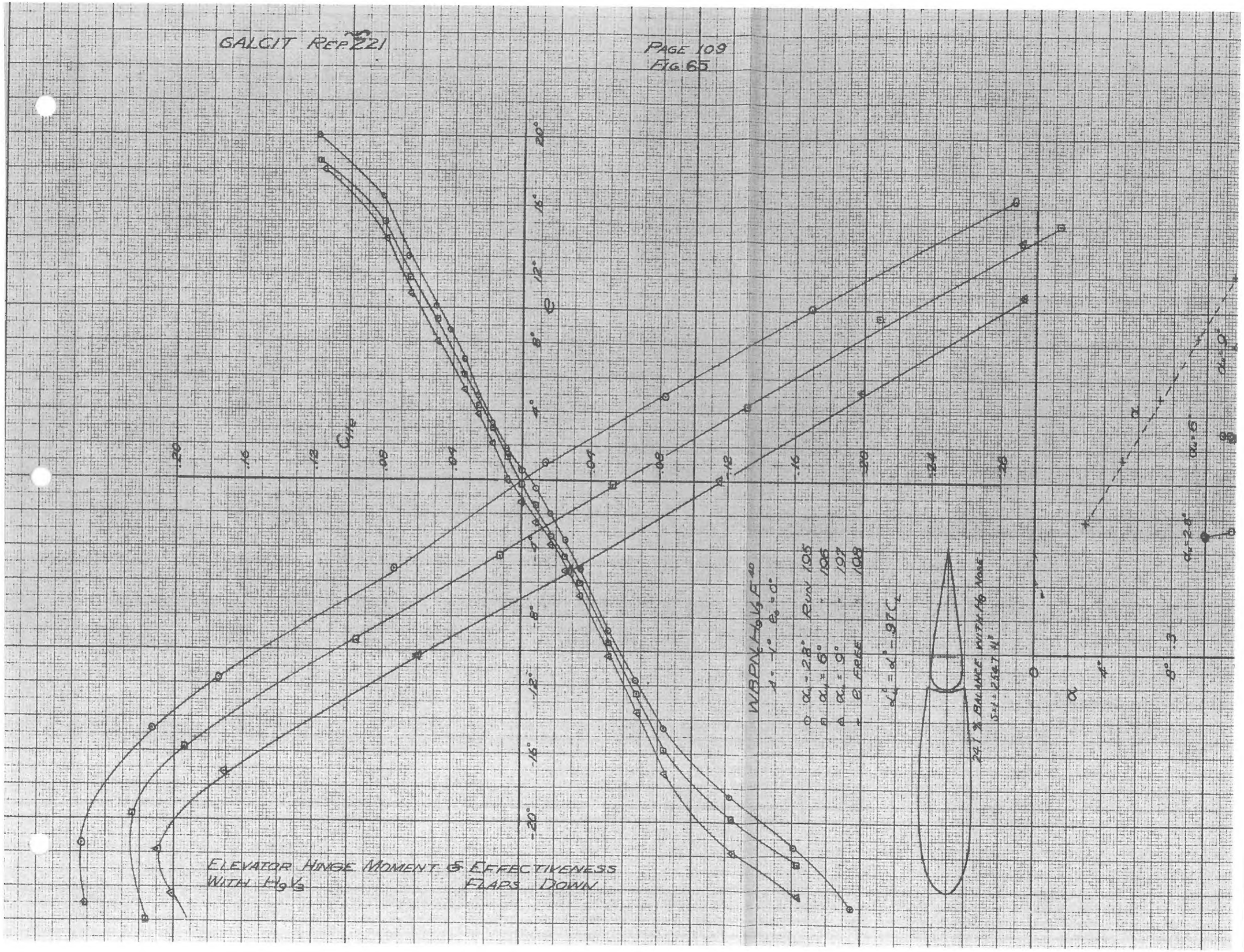


COMPARISON OF VARIOUS ELEVATORS ($H_{3,5,6,7,8}$)
STABILITY WITH ELEVATOR FREE



ELEVATOR HINGE MOMENT & EFFECTIVENESS WITH H_1V_3


24.1 % BALANCE WITH H.B MASS
20
0°
4°
5°
12°
6°
4°
8°
α
$C_{m_{c/4}}$
2
1
0
-1
-2
C_L
α_w=28°
α_w=6°
α_w=0°
α_w=12°



ELEVATOR HINGE MOMENT & EFFECTIVENESS WITH $H_9 V_3$ FLAPS DOWN

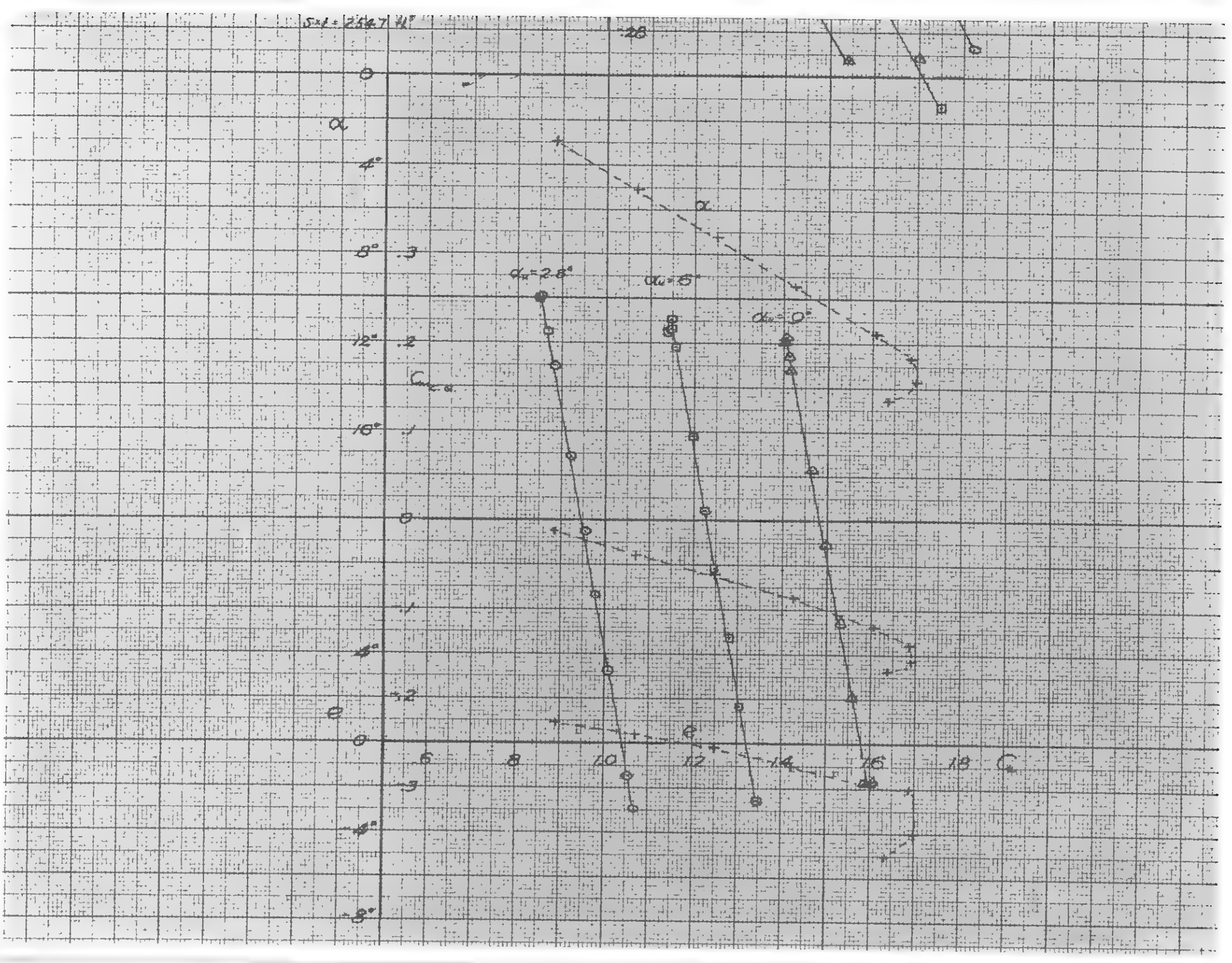

S = 254.7 ft²
α
$C_{L\alpha}$
α_w = 2.8°
α_w = 5°
α_w = 0°
6
8
10
12
14
16
18
C_L

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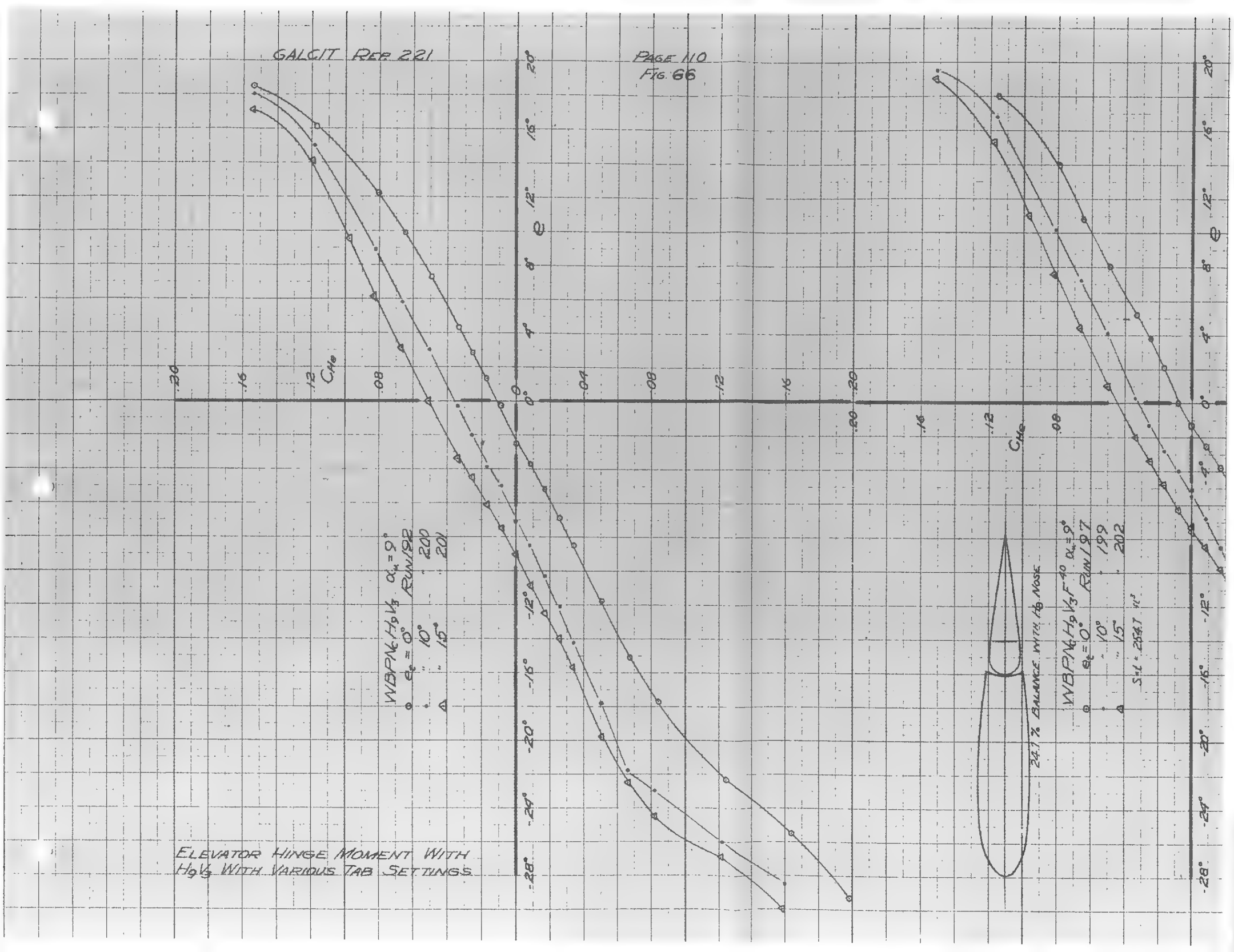
FIG. 66



ELEVATOR HINGE MOMENT WITH H0 V3 WITH VARIOUS TAB SETTINGS

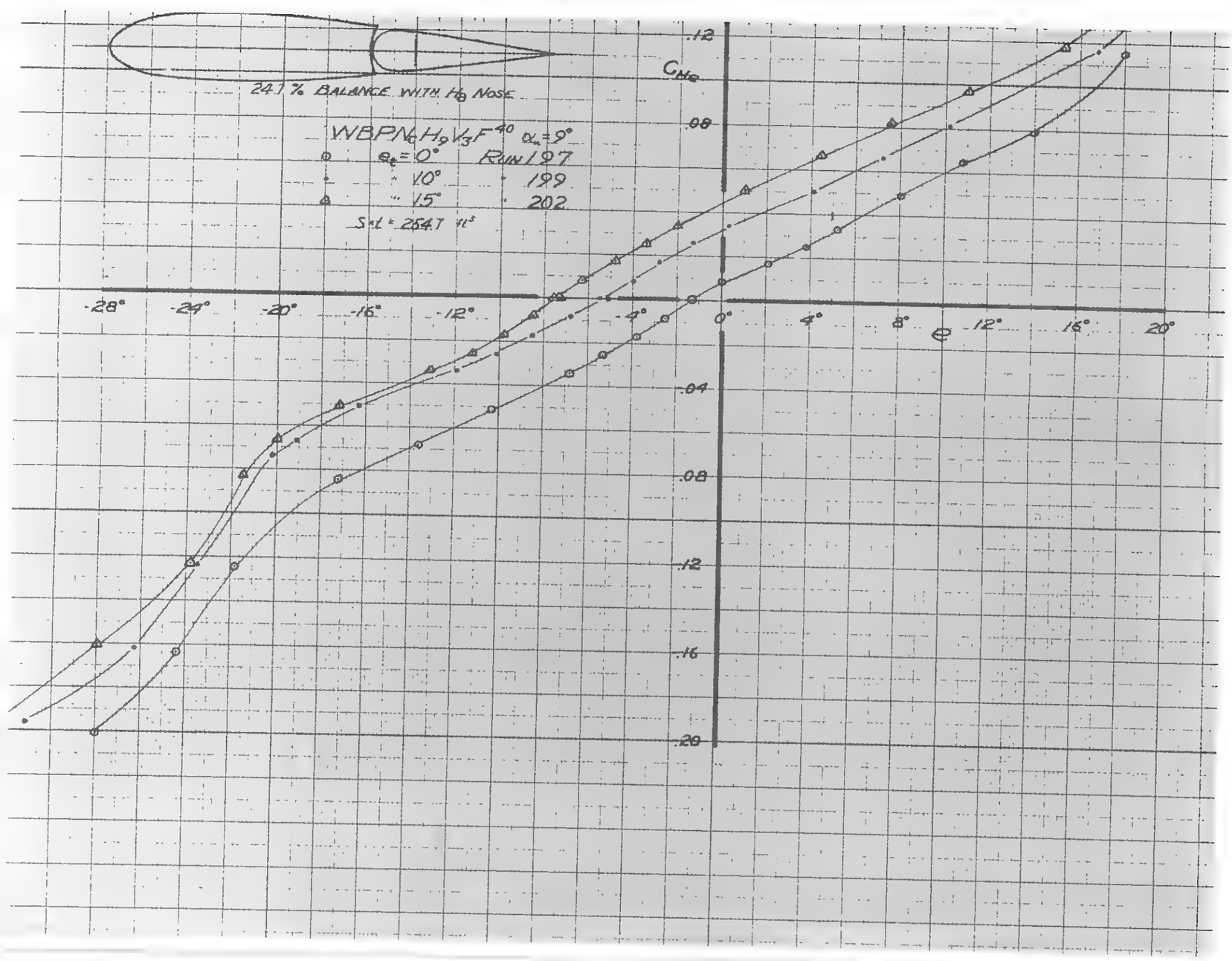

24.1 % BALANCE WITH H6 NOSE
WBPN6H2V3F40 αw=9°
ε=0° RUN 197
" 10° " 199
" 15° " 202
S=L=264.1 ft²
.12
.08
.04
-.04
-.08
-.12
-.16
-.20
-28°
-24°
-20°
-16°
-12°
-8°
-4°
0°
4°
8°
12°
16°
20°
ε

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FIG. 67

ELEVATOR HINGE MOMENT
& EFFECTIVENESS WITH $H_0 V_3$

C_{H_e} AND $C_{M_{c.g.}}$

27.3% BALANCE WITH H_0 NOSE
$S_{H_e} = 2.547$ ft²

WBPN $c_{H_0} H_{0_e} V_3$, $\mu = 1.0$°

○	$\alpha_u = 2.8$°	$c_t = 0$°	Run 203
□	" = 6°	"	204
△	" = 9°	"	205
×	" = 12°	"	206
-+-	e FREE	"	207

$\alpha_u = \alpha - .97 C_L$

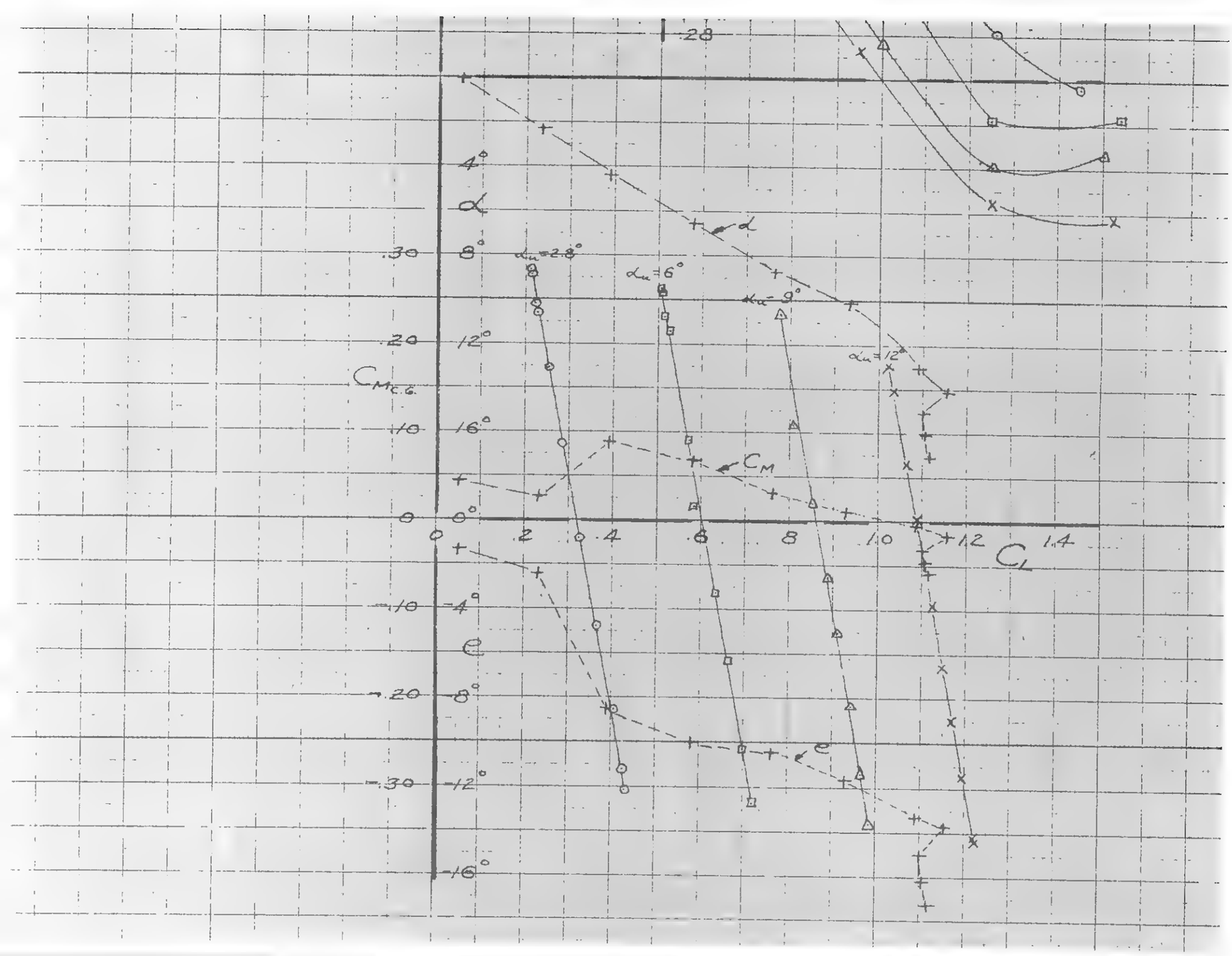
.28
4°
α
.30
8°
α_w=2.8°
α_w=6°
α_w=9°
α_w=12°
.20
12°
$C_{M_{c.g.}}$
.10
16°
C_M
0
0°
0
.2
.4
.6
.8
1.0
1.2
1.4
C_L
-.10
-4°
e
-.20
-8°
-.30
-12°
-16°

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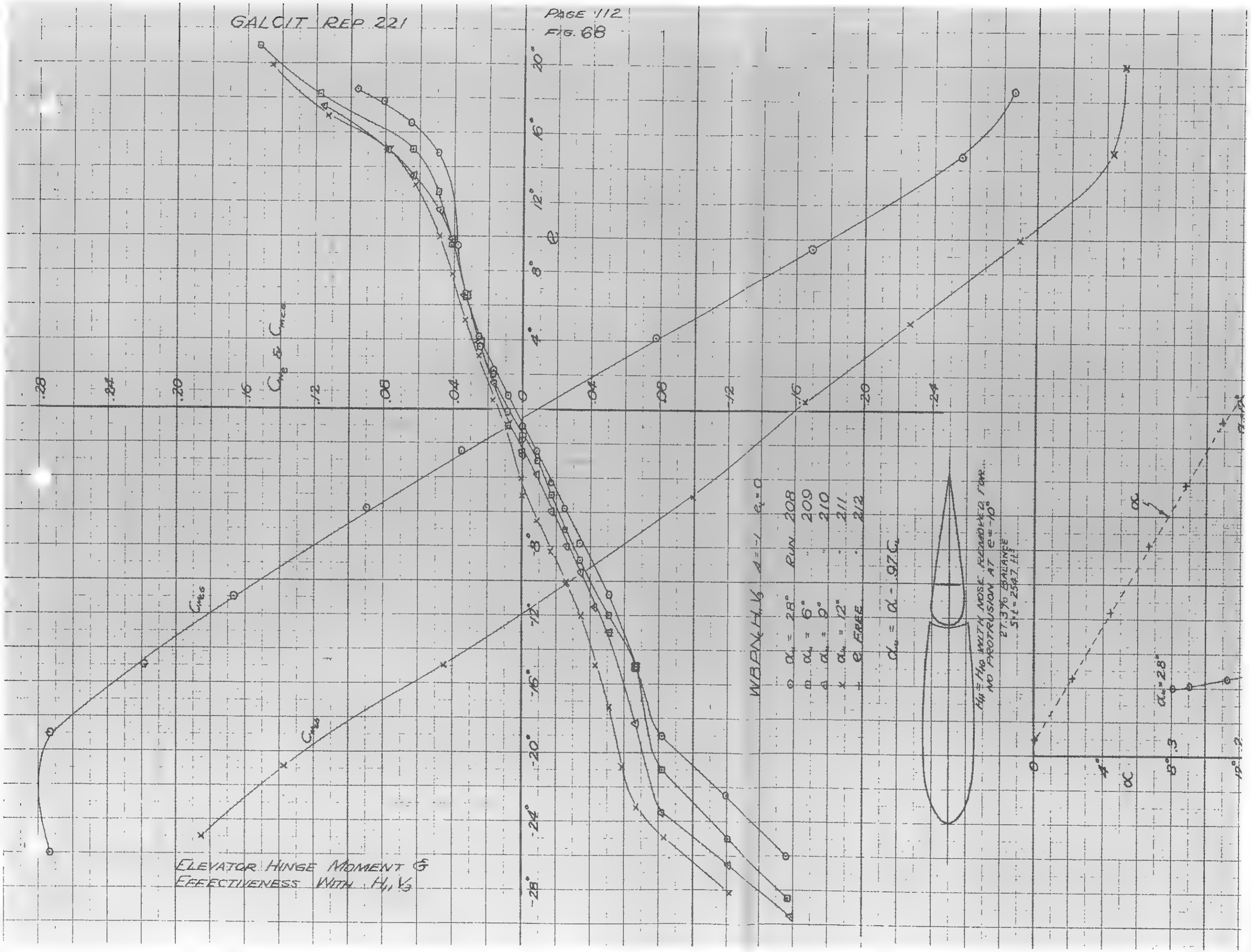
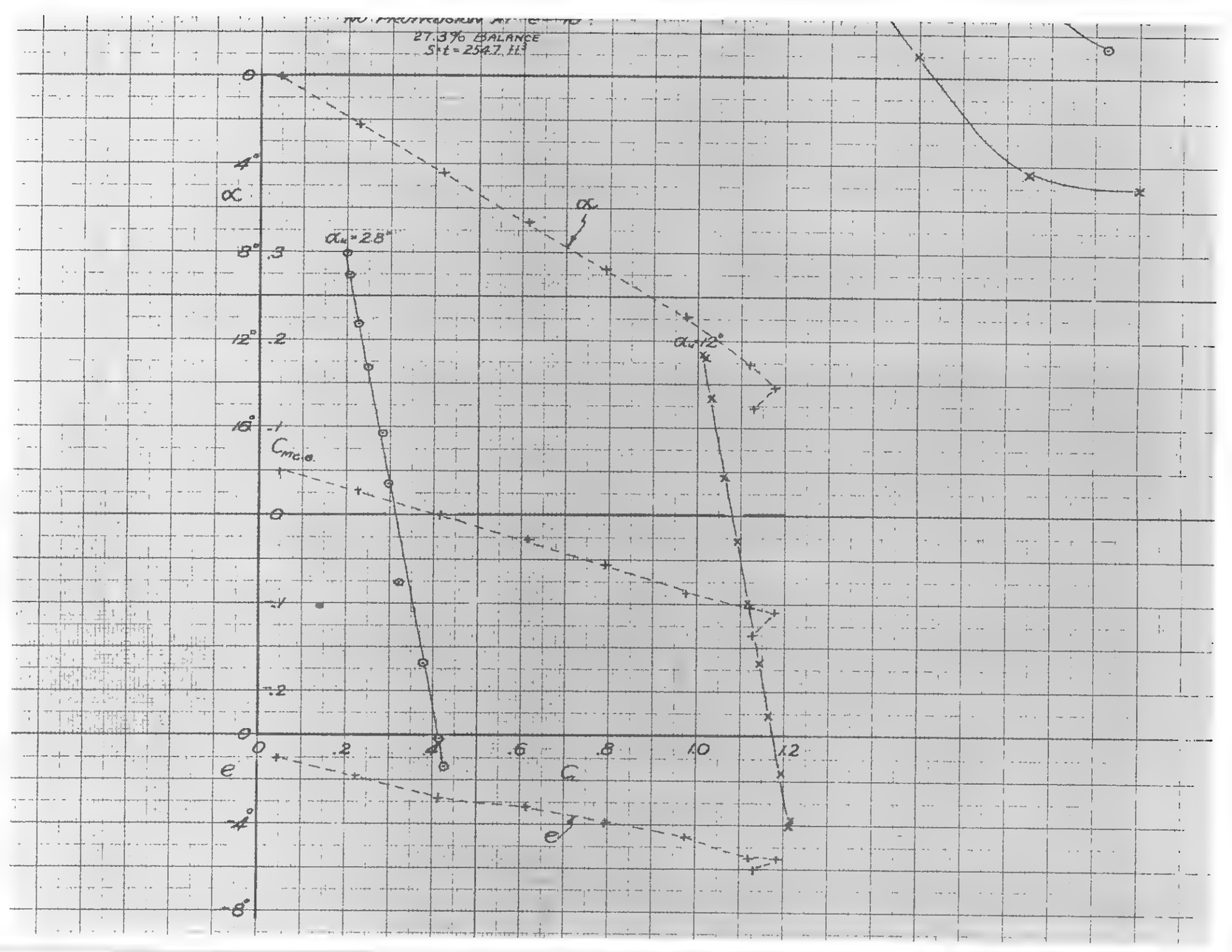
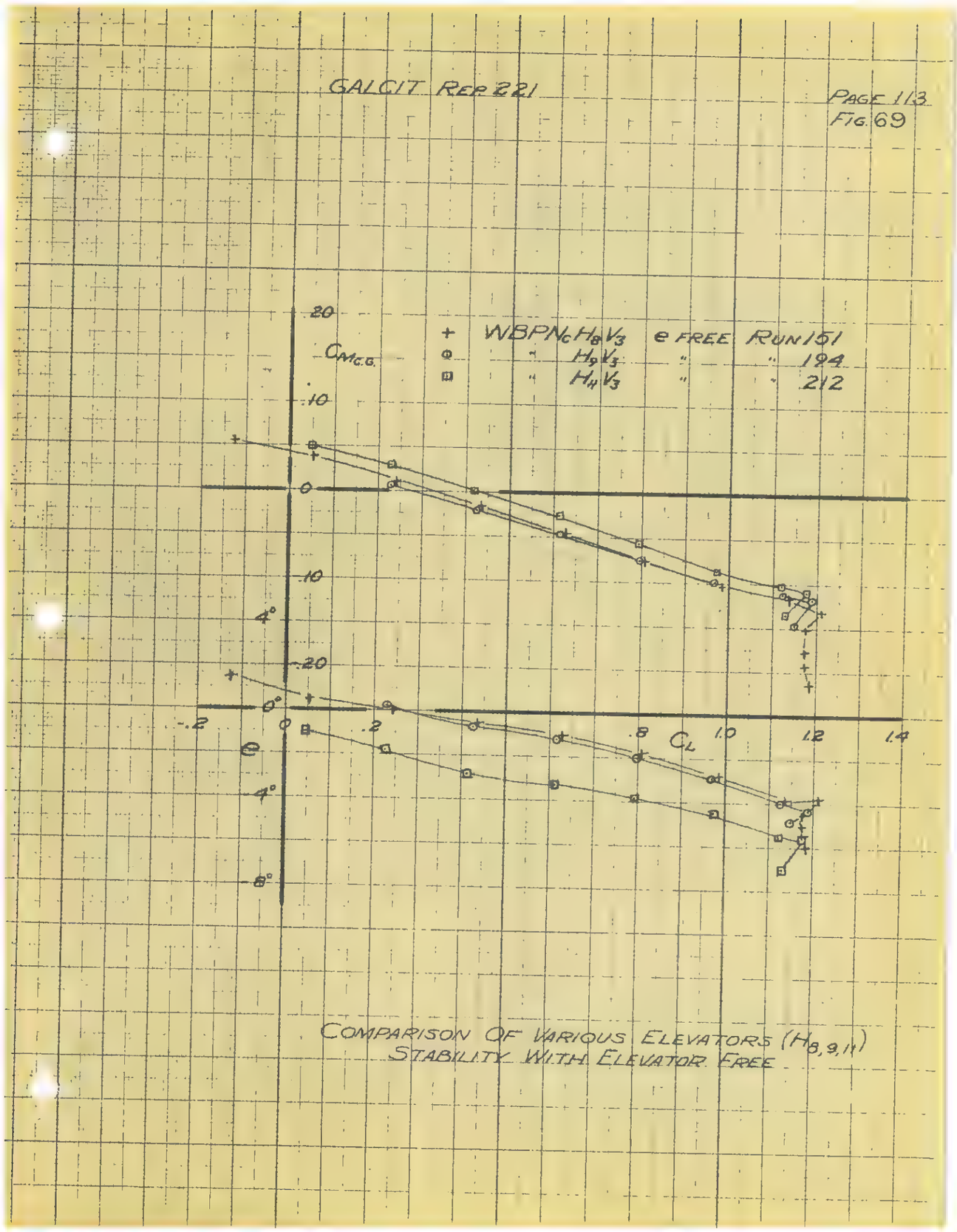
FIG. 68



ELEVATOR HINGE MOMENT & EFFECTIVENESS WITH H_1, V_3


27.3% BALANCE
S·t = 254.7 ft²
α
$\alpha_{L=0}$ = 2.8°
$\alpha_{L=12°}$
$C_{m c.g.}$
C_L
e
0
4°
8°
12°
16°
.2
.4
.6
.8
1.0
1.2
-.1
-.2
-.3
-.4



COMPARISON OF VARIOUS ELEVATORS ($H_{8,9,11}$)
STABILITY WITH ELEVATOR FREE

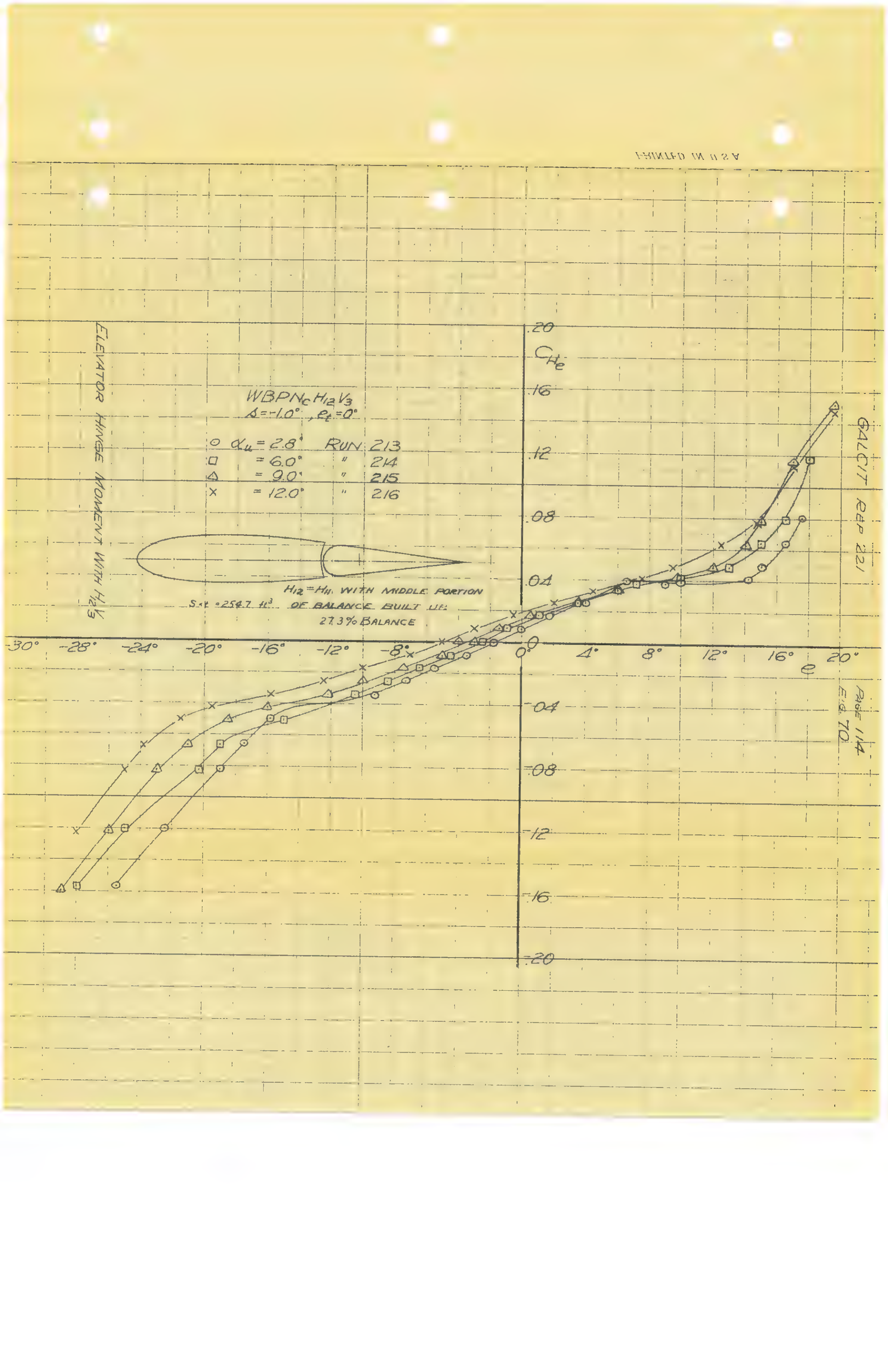

ELEVATOR HINGE MOMENT WITH $H_{12}V_3$
C_{H_e}
$WBPN_0H_{12}V_3$
$\Delta = -1.0°$, $\varepsilon_t = 0°$
○ $\alpha_u = 2.8°$ RUN 213
□ = 6.0° " 214
△ = 9.0° " 215
× = 12.0° " 216
H_{12} = H_{11} WITH MIDDLE PORTION
OF BALANCE BUILT UP.
27.3% BALANCE
$S_{ht} = 25.47$ ft²
.20
.16
.12
.08
.04
-.04
-.08
-.12
-.16
-.20
-30° -28° -24° -20° -16° -12° -8° 0° 4° 8° 12° 16° 20°
e
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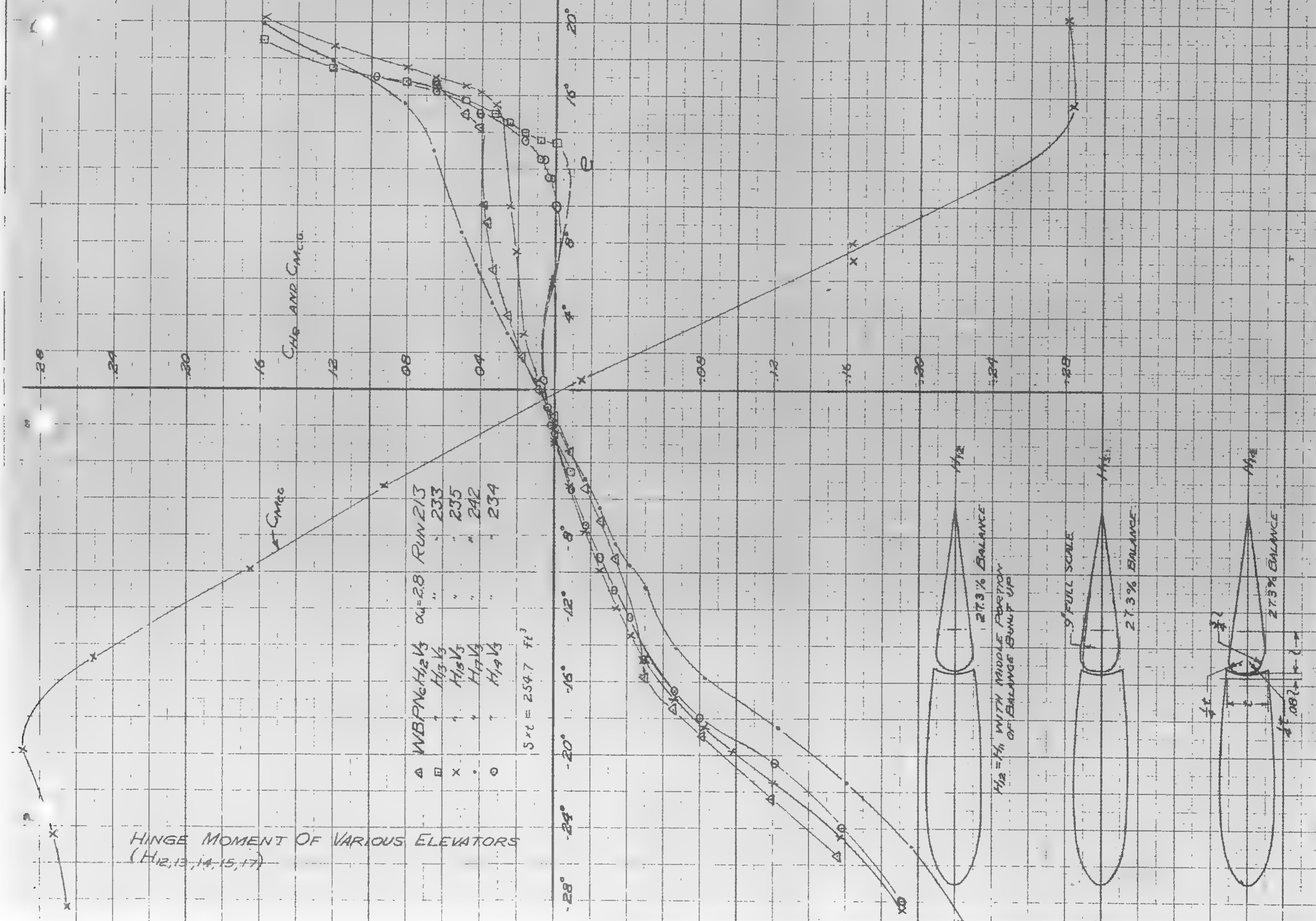
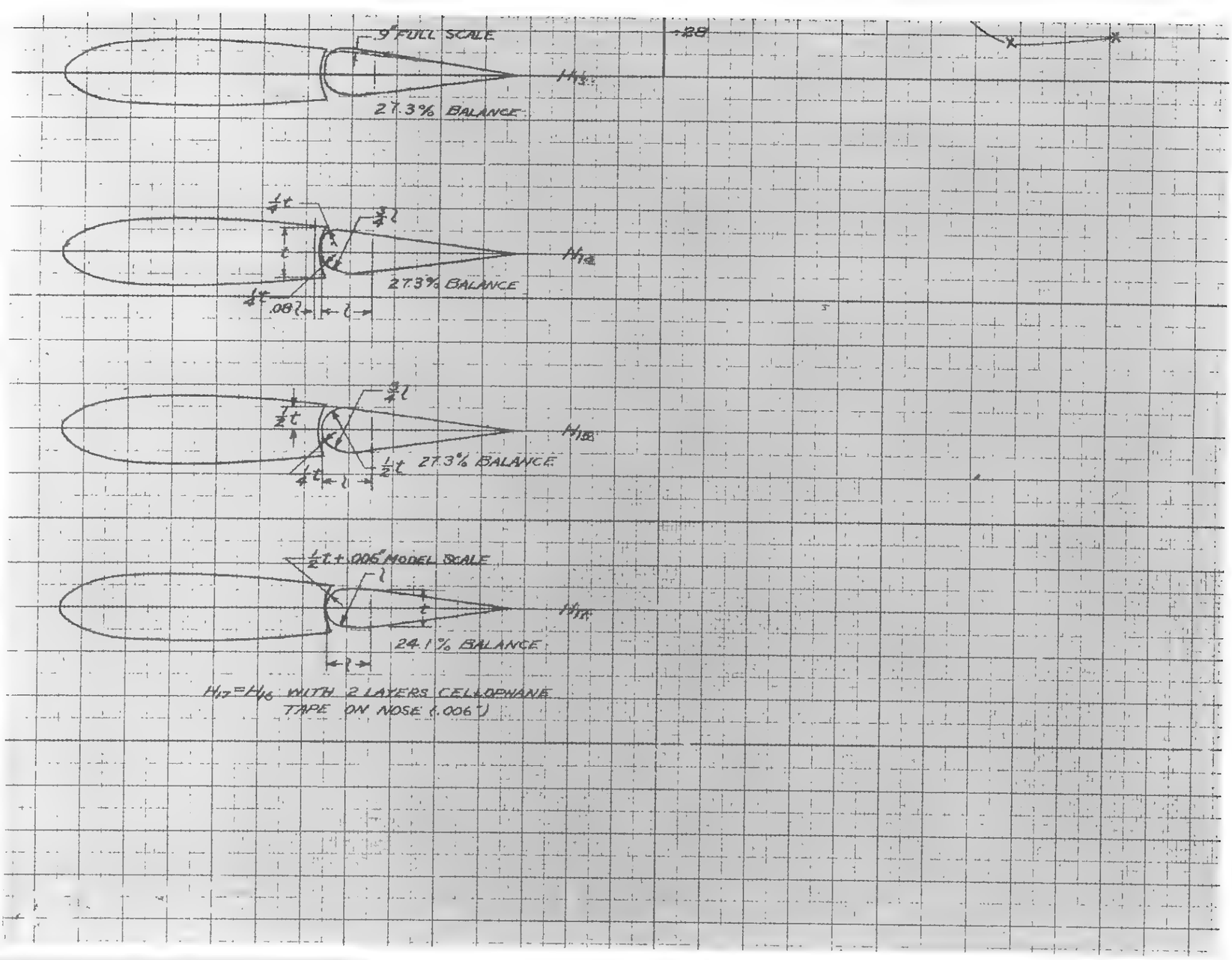
Fig. 70



HINGE MOMENT OF VARIOUS ELEVATORS
($H_{12,13,14,15,17}$)



$H_{17} = H_{16}$ WITH 2 LAYERS CELLOPHANE TAPE ON NOSE (.006")

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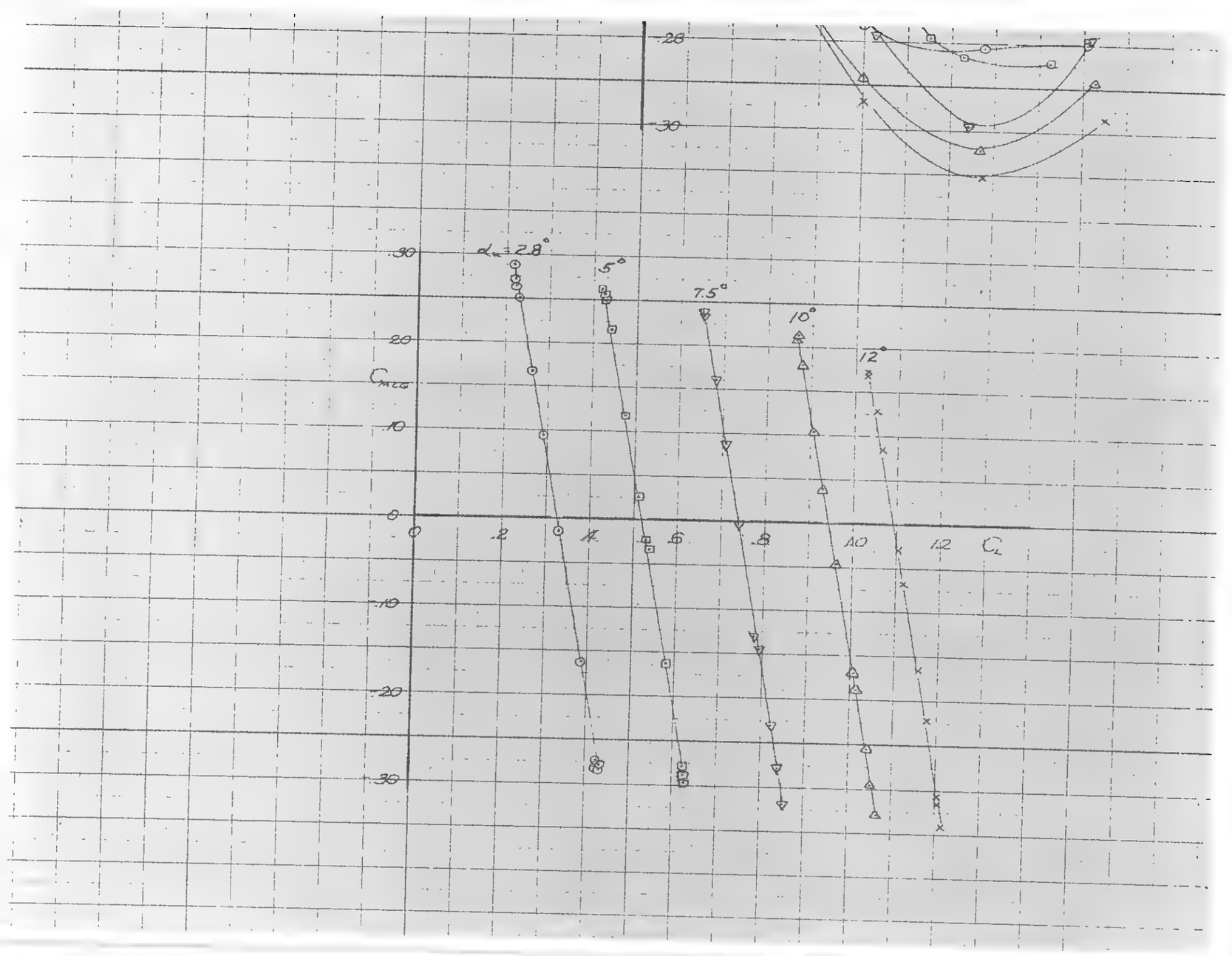
FIG 72

ELEVATOR HINGE MOMENT & EFFECTIVENESS
WITH $H_{1.6}$ V_3


-28
-30
.30
20
$C_{m_{c/4}}$
10
0
-10
-20
-30
α_c=2.8°
5°
7.5°
10°
12°
0
.2
.4
.6
.8
1.0
1.2
C_L

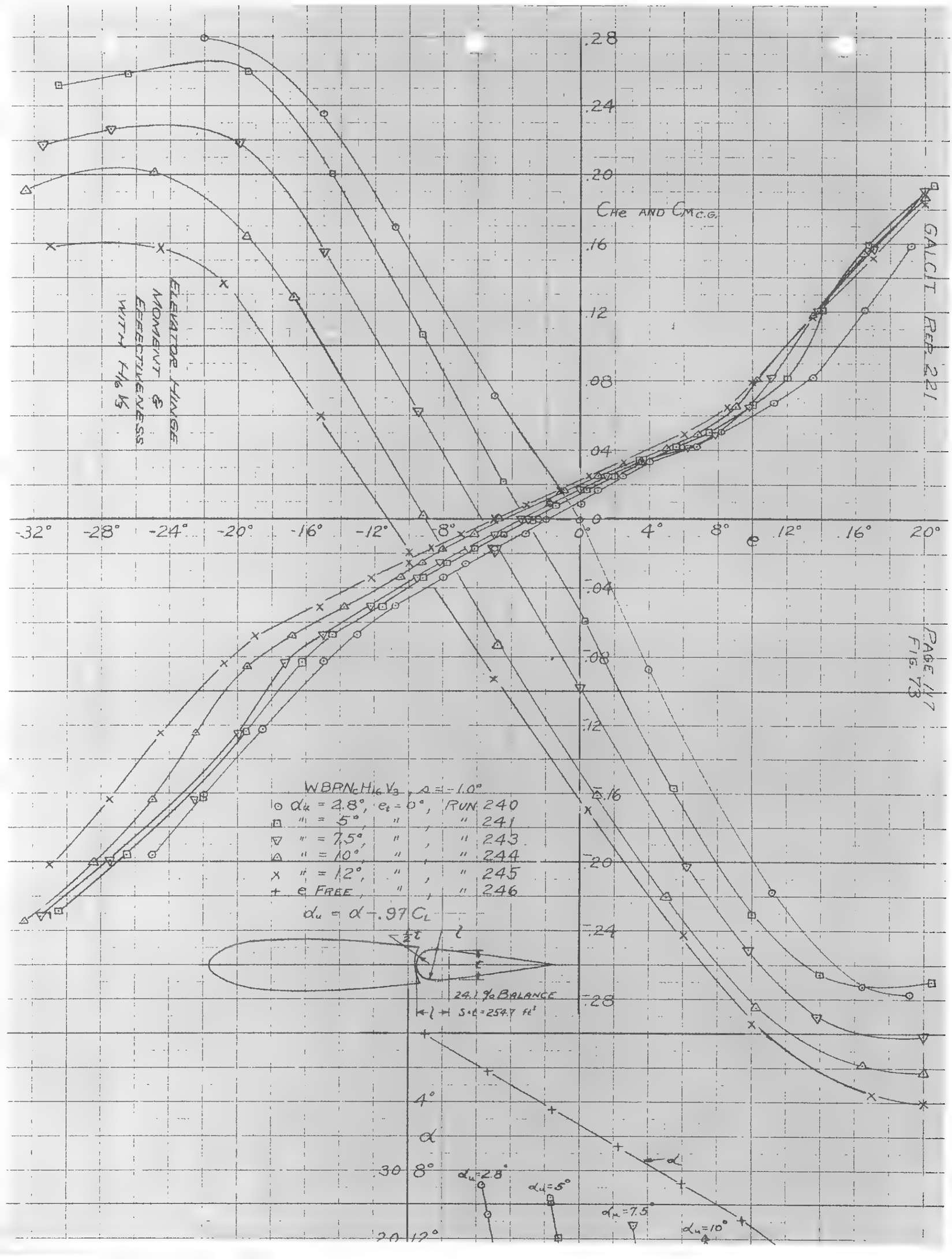

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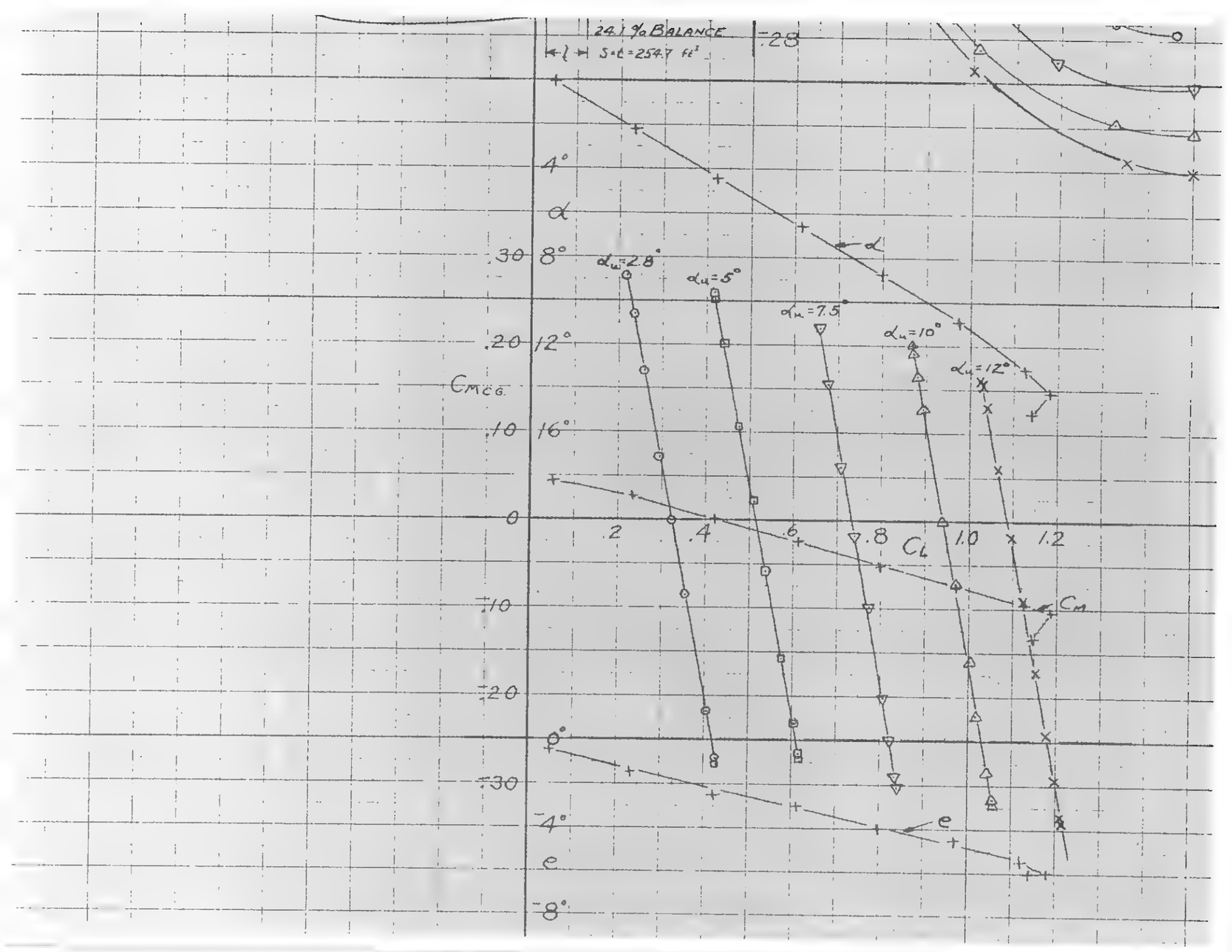
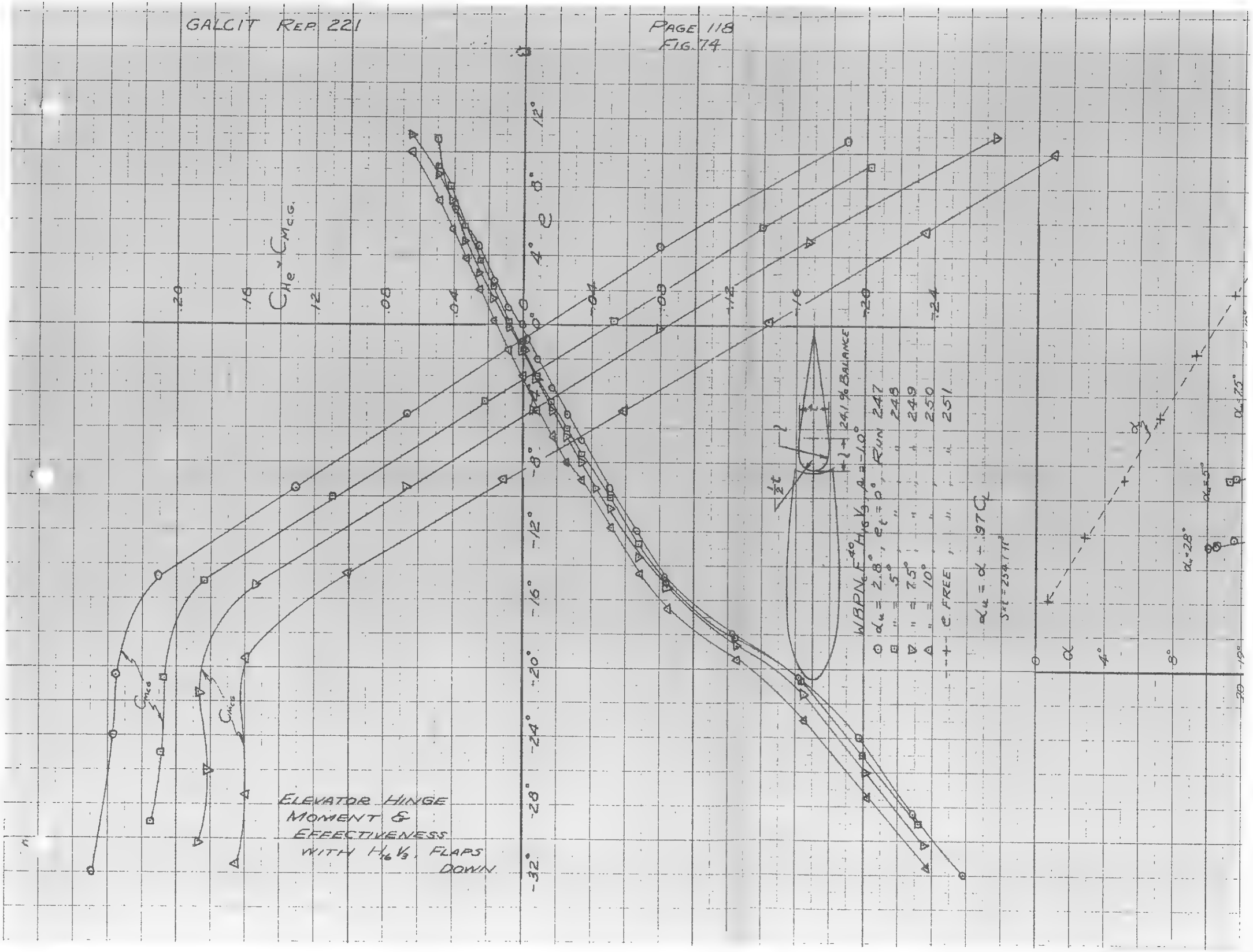
FIG. 73
CHE AND CMC.G.
ELEVATOR HINGE MOMENT & EFFECTIVENESS WITH 41% S
WBPNcHIcV3, Δ = -1.0°
αu = 2.8°, et = 0°, RUN 240
" = 5°, " , " 241
" = 7.5°, " , " 243
" = 10°, " , " 244
" = 12°, " , " 245
e FREE, " , " 246
αu = α - .97 CL
24.1% BALANCE
S.E. = 254.7 ft²
α
αu=2.8°
αu=5°
αu=7.5°
αu=10°


24.1% BALANCE
S=L=254.7 ft²
-.28
4°
α
8°
12°
16°
0°
-4°
e
-8°
.30
.20
.10
0
-.10
-.20
-.30
Cmc.g.
.2
.4
.6
.8
CL
1.0
1.2
Cm
αw=2.8°
αw=5°
αw=7.5°
αw=10°
αw=12°



ELEVATOR HINGE MOMENT & EFFECTIVENESS WITH H_{16} V_3 FLAPS DOWN

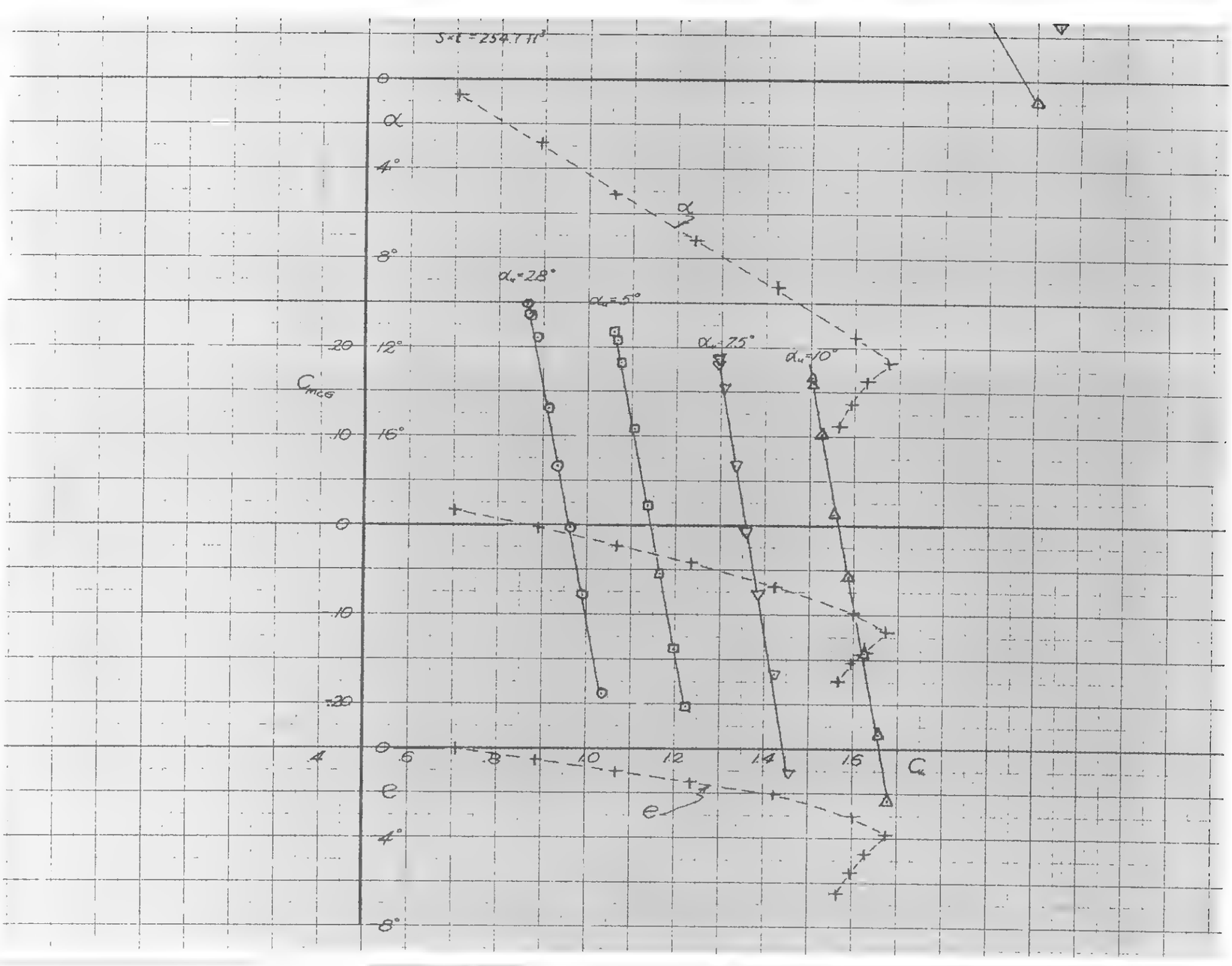

S·t = 254.7 in²
α
4°
8°
12°
16°
0
-4°
-8°
C_{mcs}
.20
.10
0
-.10
-.20
α_w=2.8°
α_w=5°
α_w=7.5°
α_w=10°
.4
.6
.8
1.0
1.2
1.4
1.6
C_L
e

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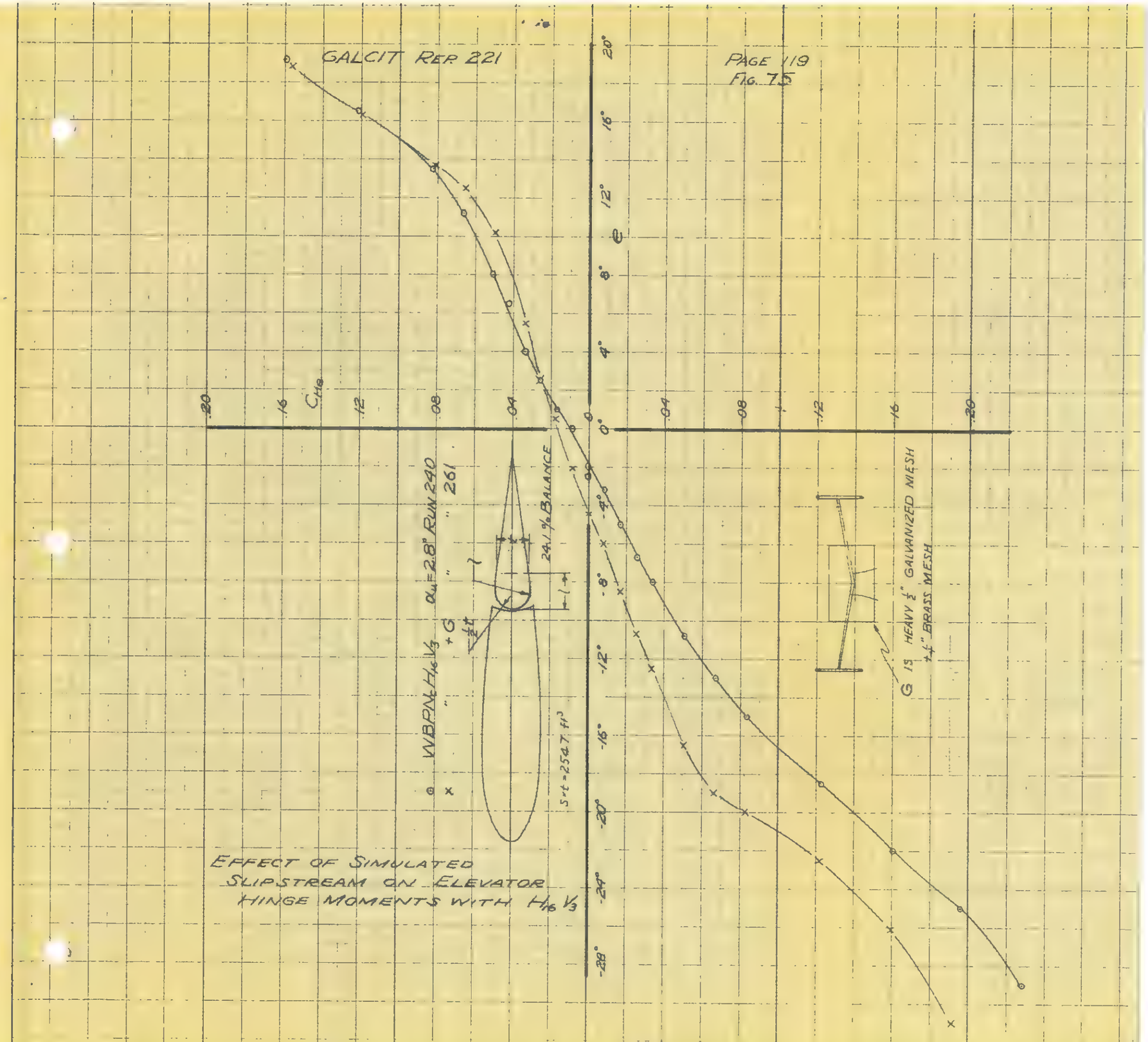
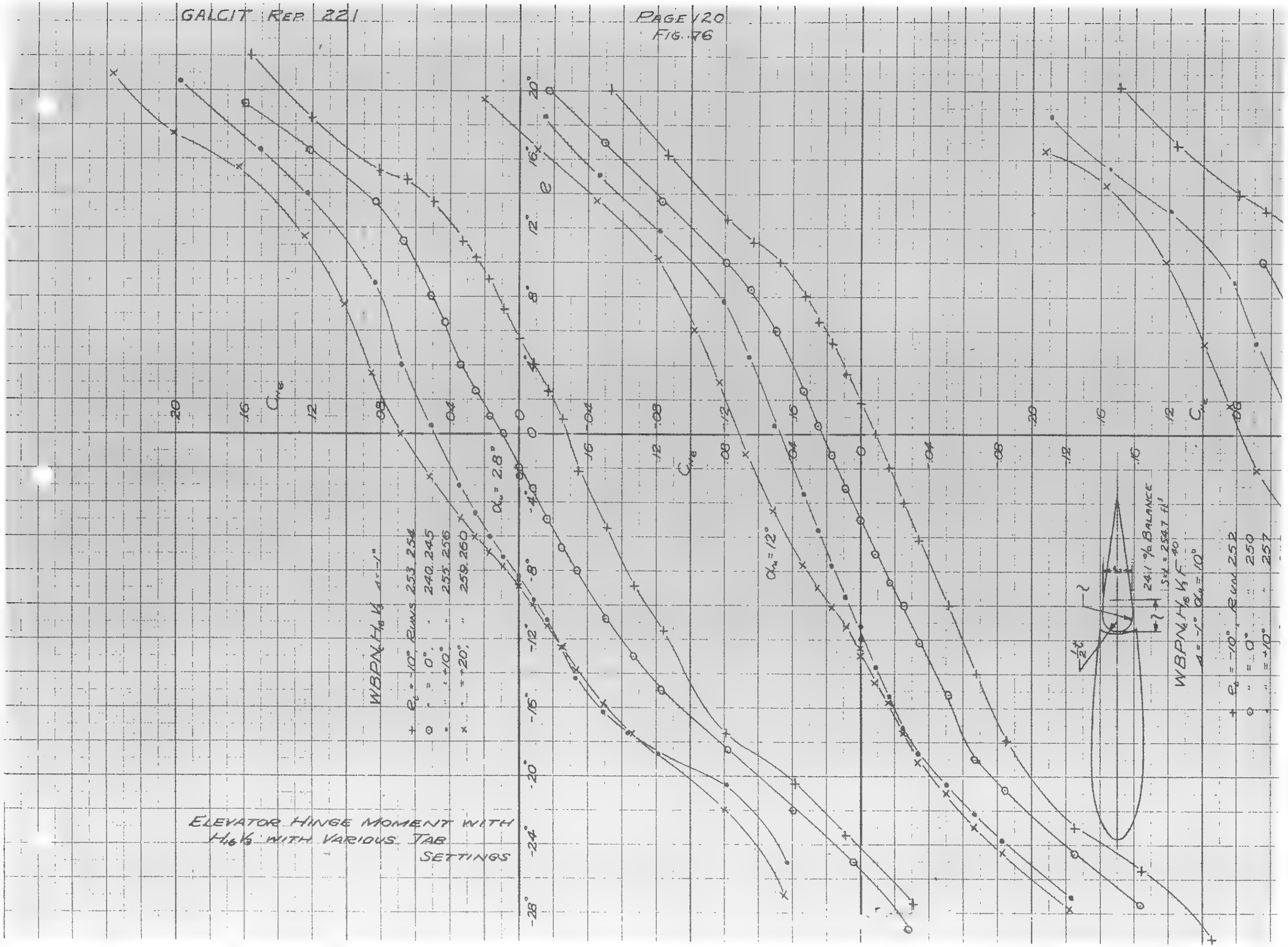
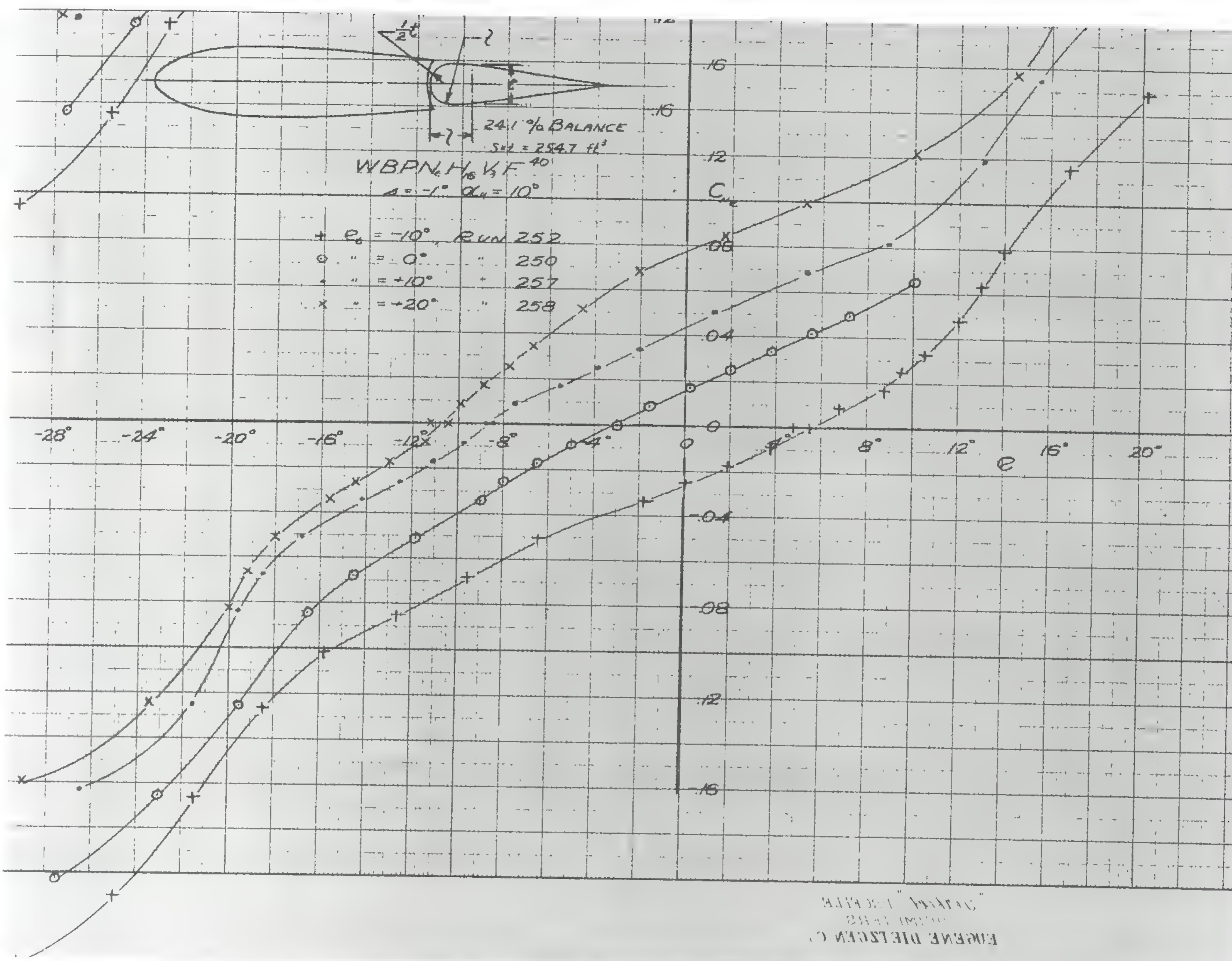
FIG. 75

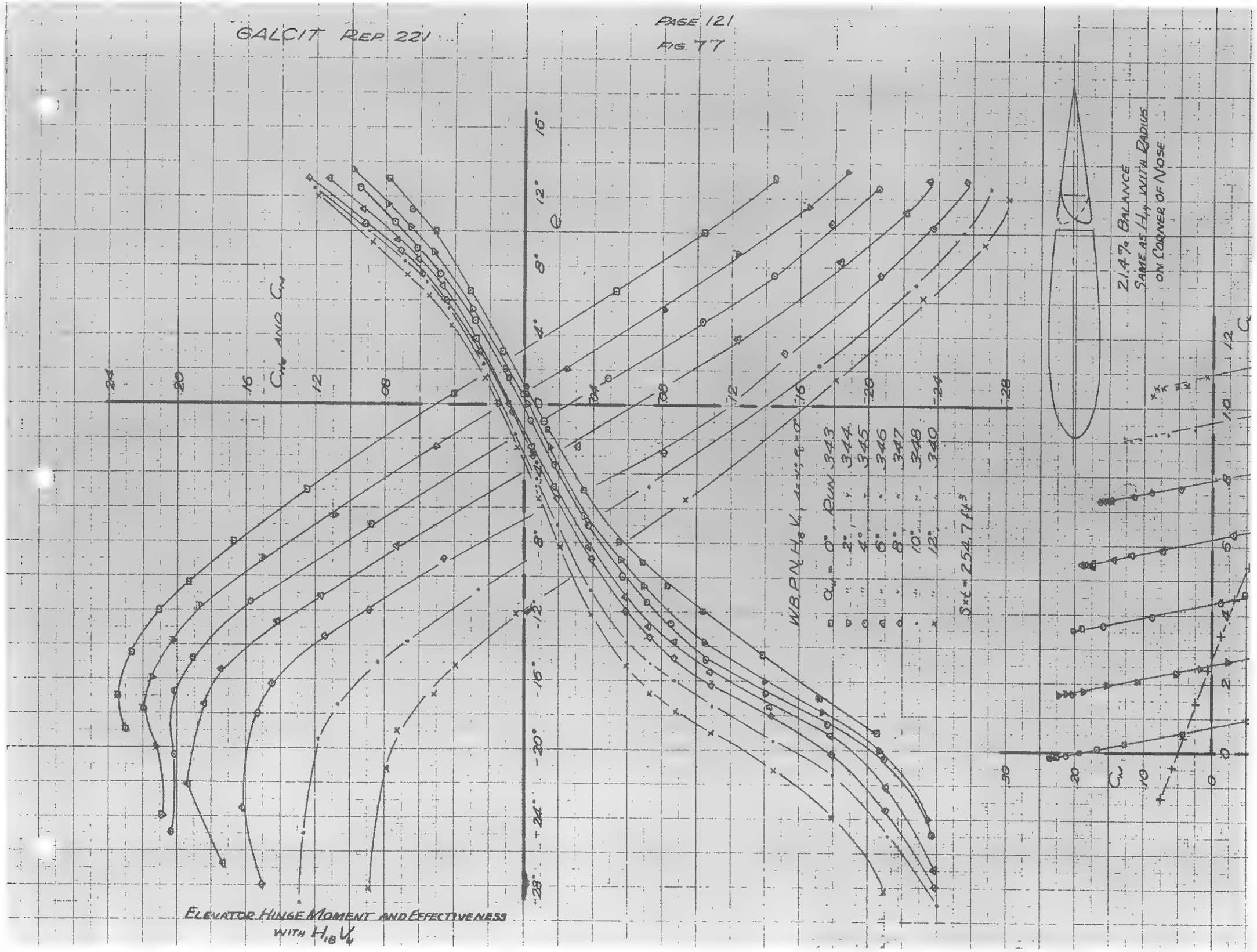


EFFECT OF SIMULATED SLIPSTREAM ON ELEVATOR HINGE MOMENTS WITH H_{16} V_3

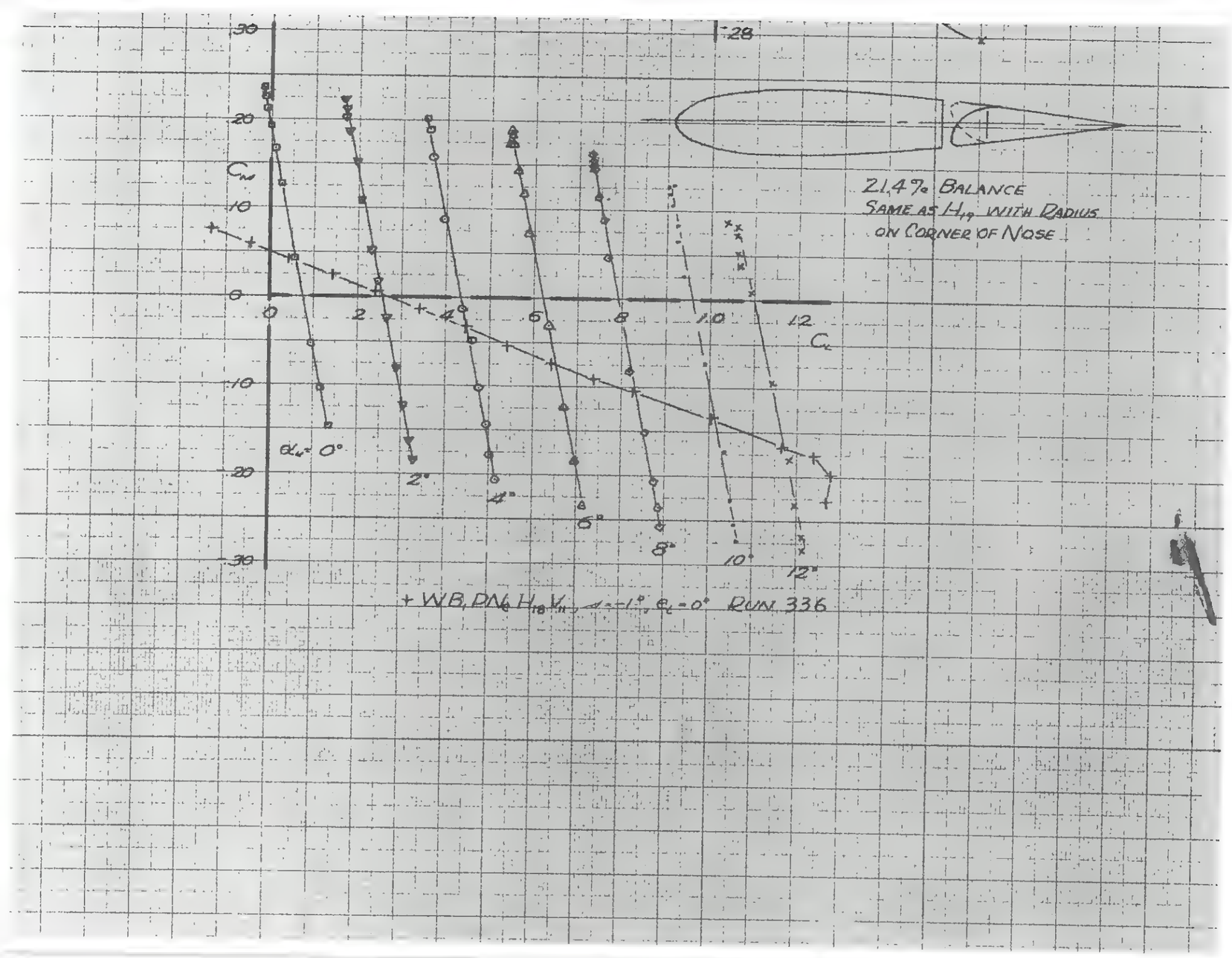


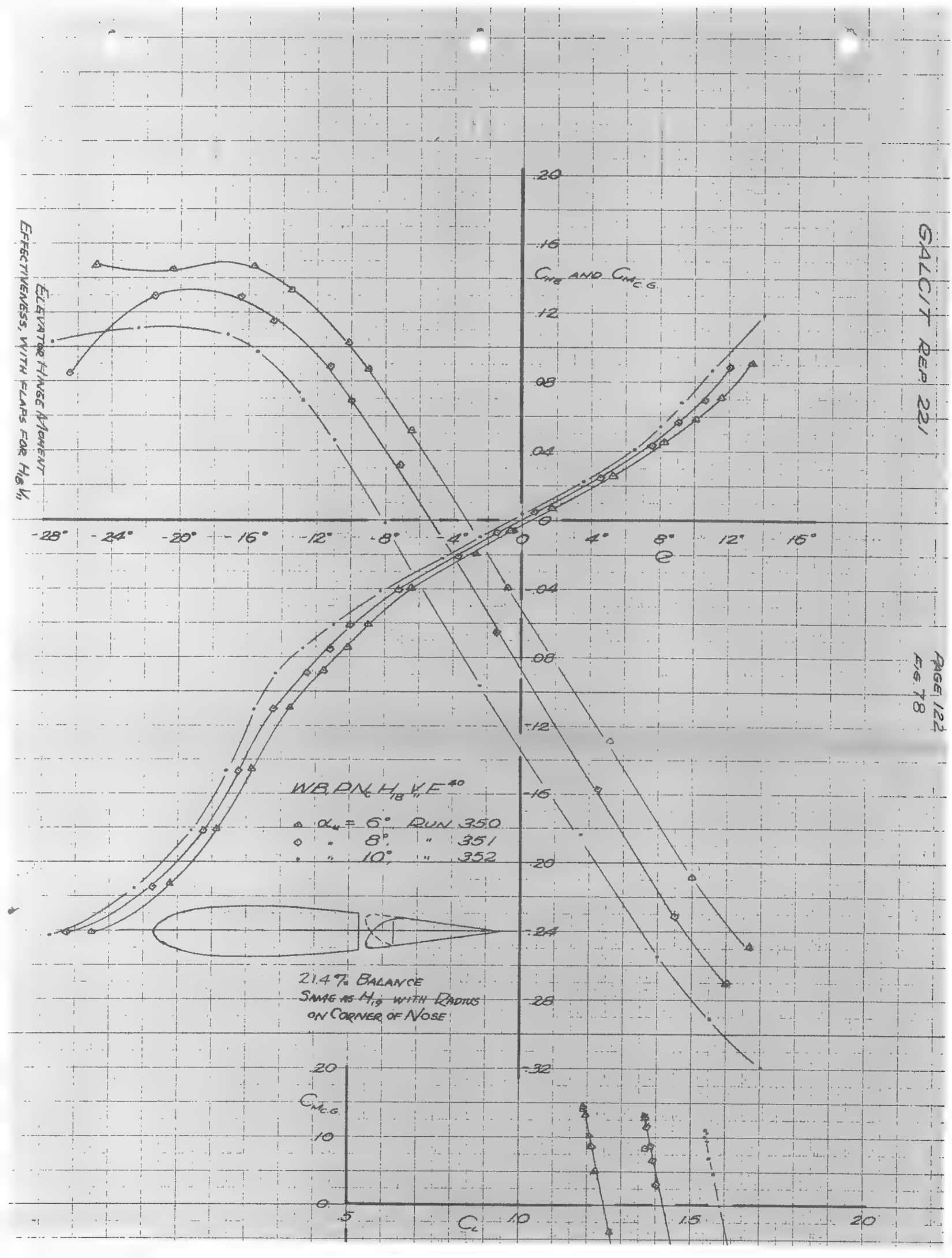
ELEVATOR HINGE MOMENT WITH $H_6 ½$ WITH VARIOUS TAB SETTINGS

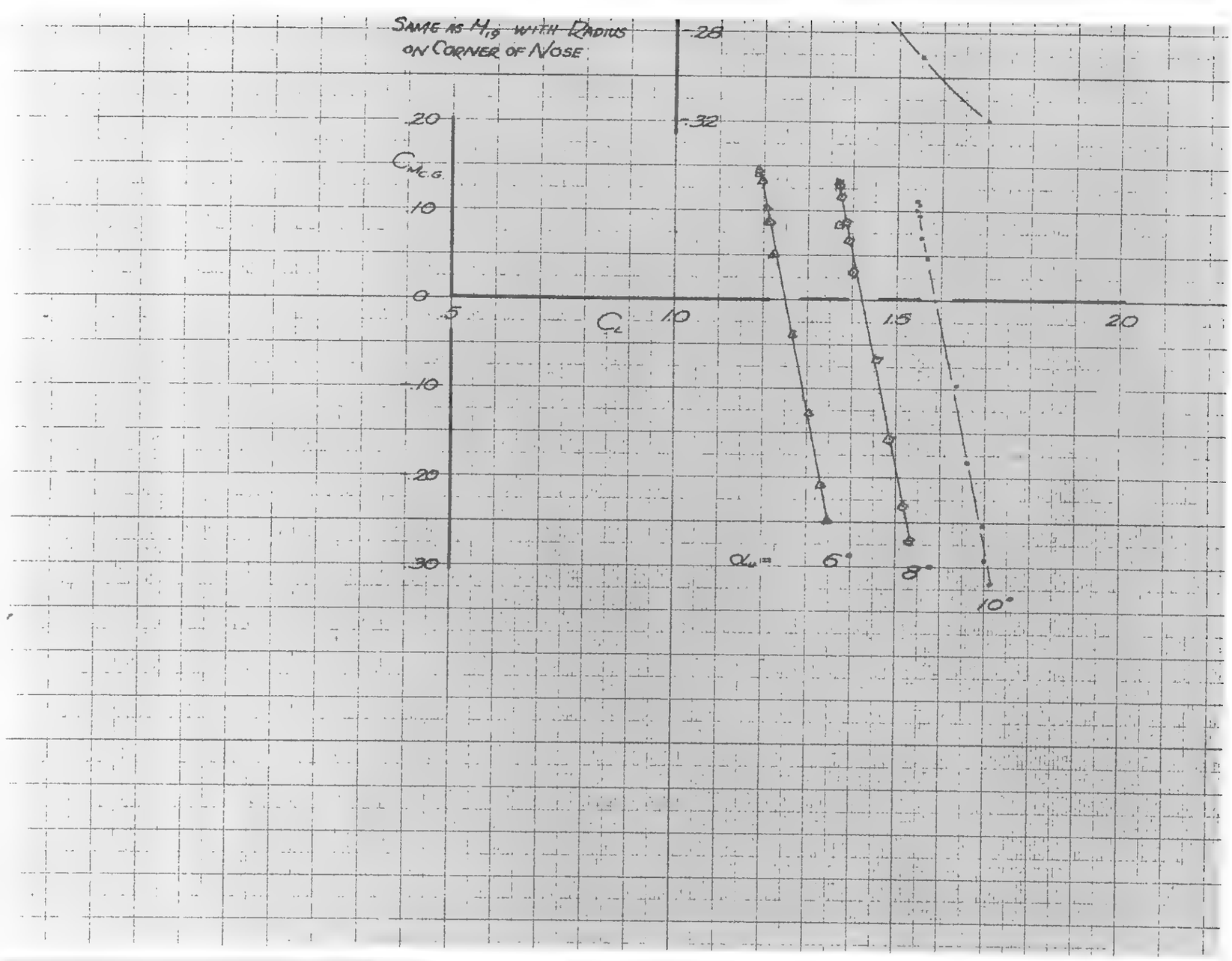

24.1 % BALANCE
$S_{H} = 254.7 \ ft^{3}$
WBPN$_{c}$H$_{16}$V$_{3}$F^{40}
$A = -1°$ $\alpha_{u} = 10°$
+ e_{t} = −10°, Run 252
⊙ " = 0° " 250
• " = +10° " 257
× " = +20° " 258
$C_{n_{e}}$
e
.16
.12
.08
.04
0
-.04
-.08
-.12
-.16
-28°
-24°
-20°
-16°
-12°
-8°
-4°
0
4°
8°
12°
16°
20°

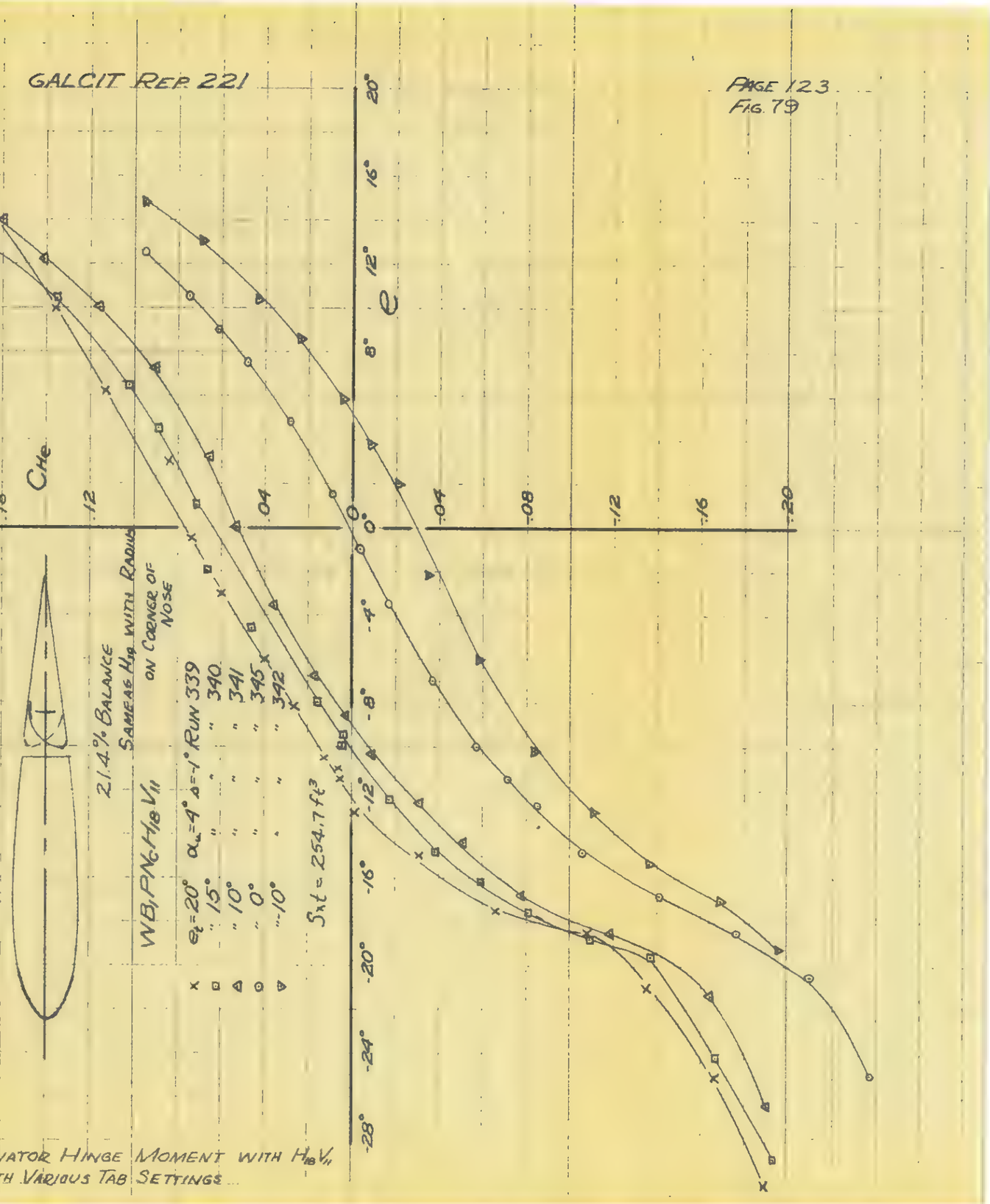


ELEVATOR HINGE MOMENT AND EFFECTIVENESS WITH H_{18} V_4


.30
.20
.10
0
-.10
-.20
-.30
C_m
0
2
4
6
8
10
12
C_L
α_t = 0°
2°
4°
6°
8°
10°
12°
.28
21.4% BALANCE
SAME AS H_{19} WITH RADIUS
ON CORNER OF NOSE
+ WB, DN6 H_{18} V_{11}, α = -1°, ϵ_t = 0° RUN 336


ELEVATOR HINGE MOMENT
EFFECTIVENESS, WITH FLAPS FOR H_{18} V_{11}
$C_{H_{18}}$ AND $C_{M_{C.G.}}$
.20
.16
.12
.08
.04
0
-.04
-.08
-.12
-.16
-.20
-.24
-.28
-.32
-28° -24° -20° -16° -12° -8° -4° 0 4° 8° 12° 15°
α
WB DN H_{18} V_{11} E 40
α_t = 6° RUN 350
" 8° " 351
" 10° " 352
21.4% BALANCE
SAME AS H_{19} WITH RADIUS
ON CORNER OF NOSE
$C_{M_{C.G.}}$
.20
.10
0
-.5
C_L
1.0
1.5
2.0


SAME AS M19 WITH RADIUS ON CORNER OF NOSE
.20
.10
0
-.10
-.20
-.30
$C_{M.C.G.}$
.5
1.0
1.5
2.0
C_L
-.28
-.32
α_w =
6°
8°
10°



ELEVATOR HINGE MOMENT WITH H_{18} V_{11} WITH VARIOUS TAB SETTINGS.

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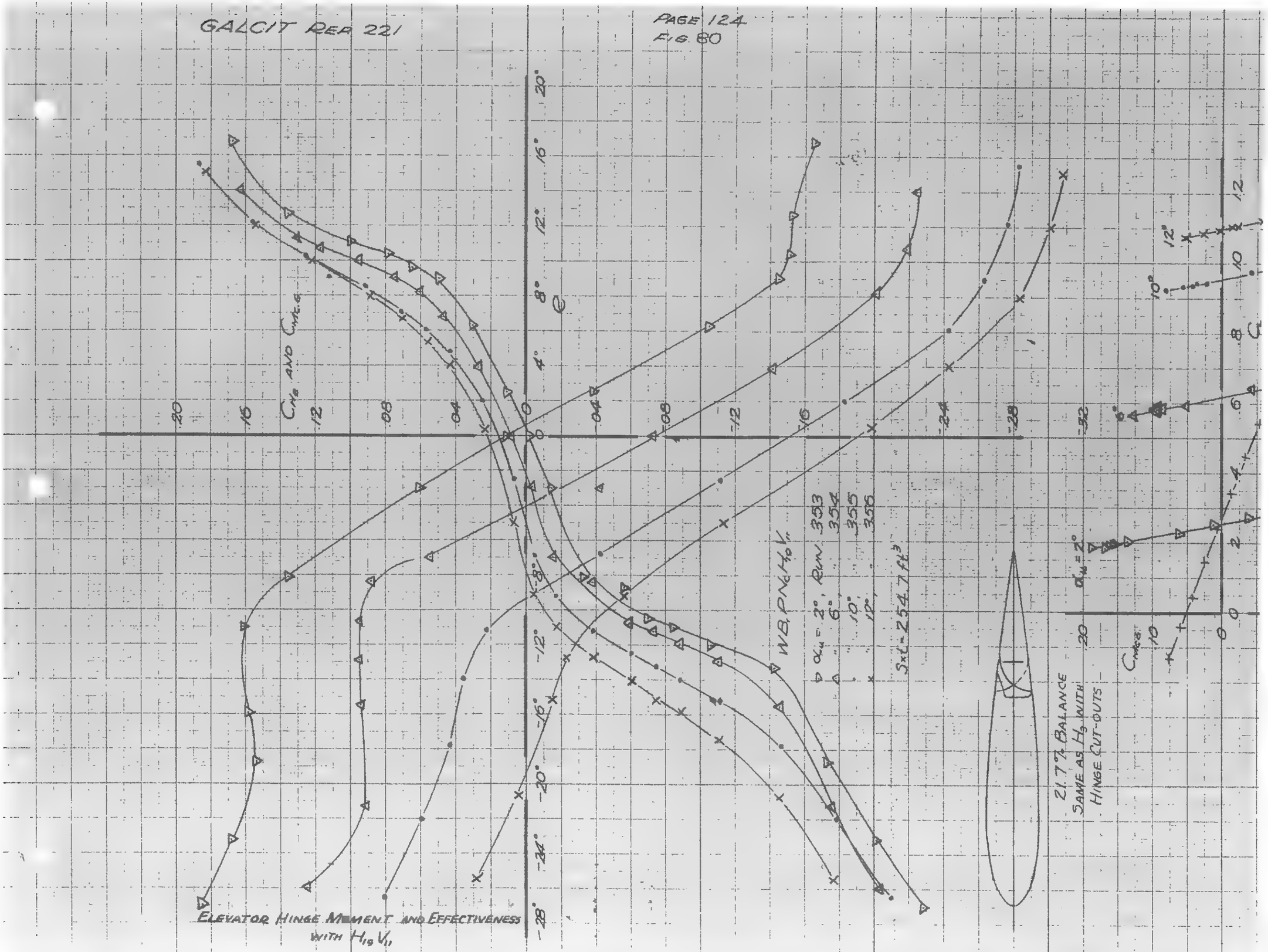
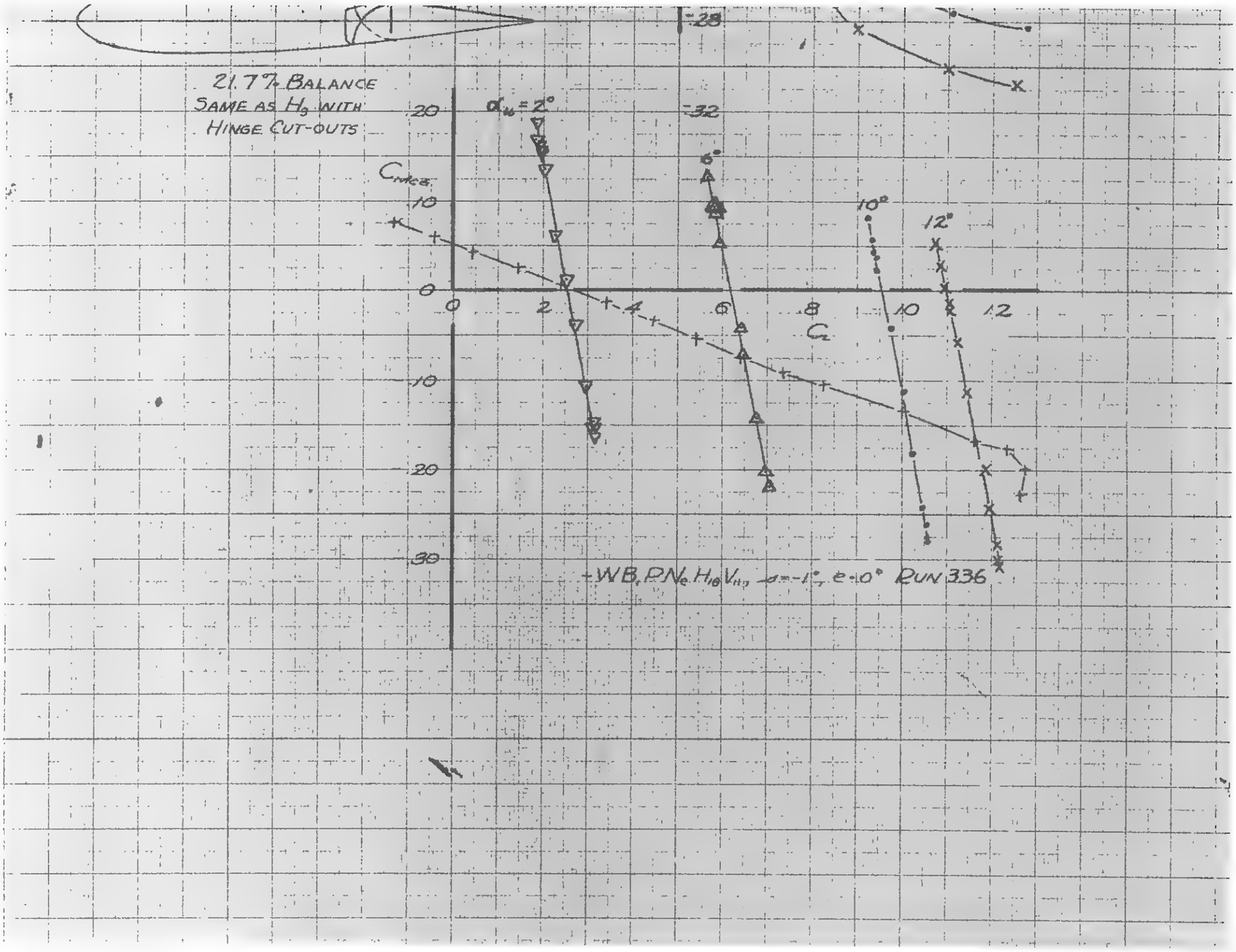
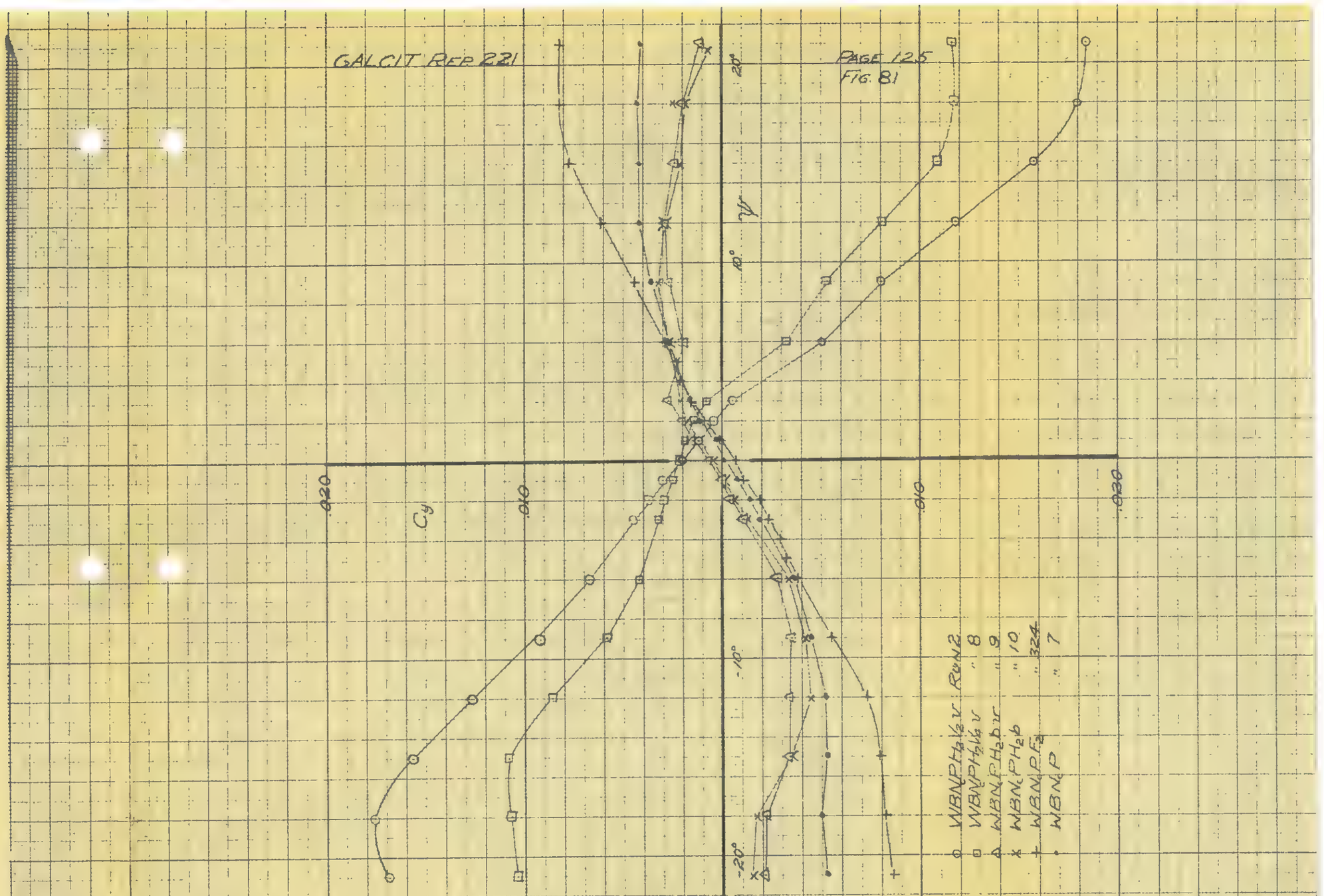
FIG. 80

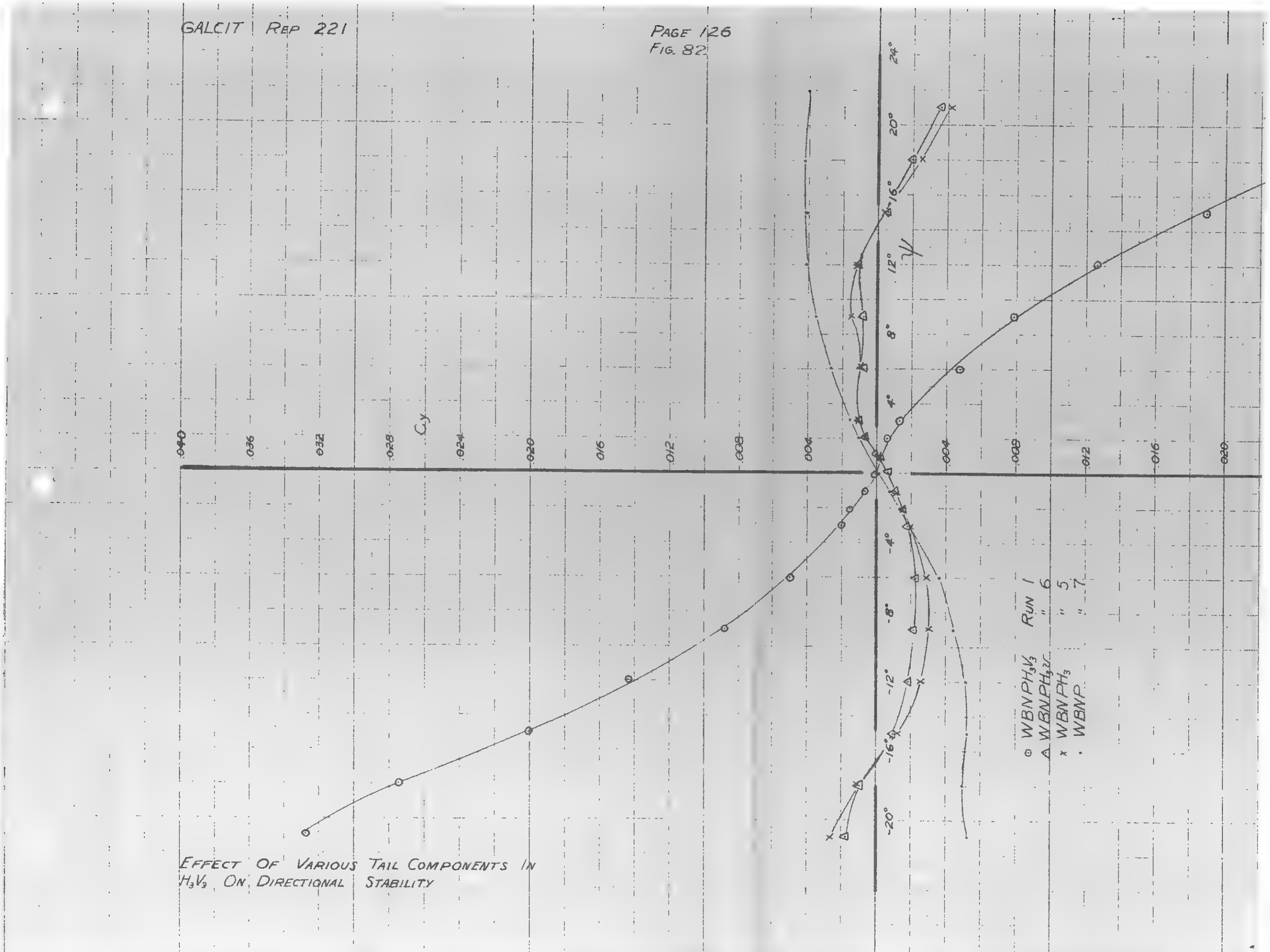


ELEVATOR HINGE MOMENT AND EFFECTIVENESS WITH $H_{1,9}$ V_1

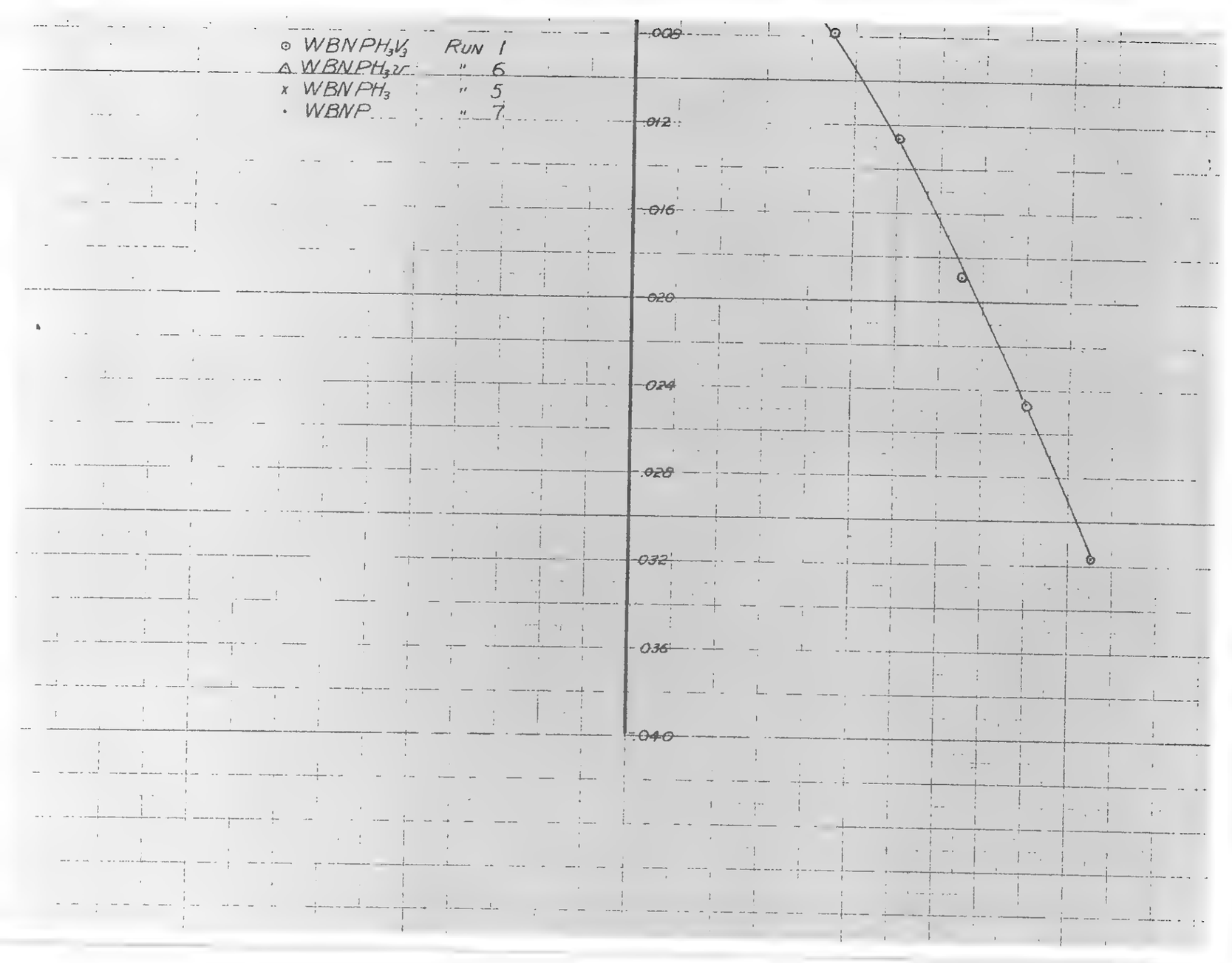

21.7% BALANCE
SAME AS H_3 WITH
HINGE CUT-OUTS
$C_{m_{c/4}}$
C_L
$\alpha_{t_0} = 2°$
6°
10°
12°
-28
-32
20
10
0
-10
-20
-30
0
2
4
6
8
10
12
+WB, PN, H_{10} V_{11}, i_t=-1°, e-10° RUN 336

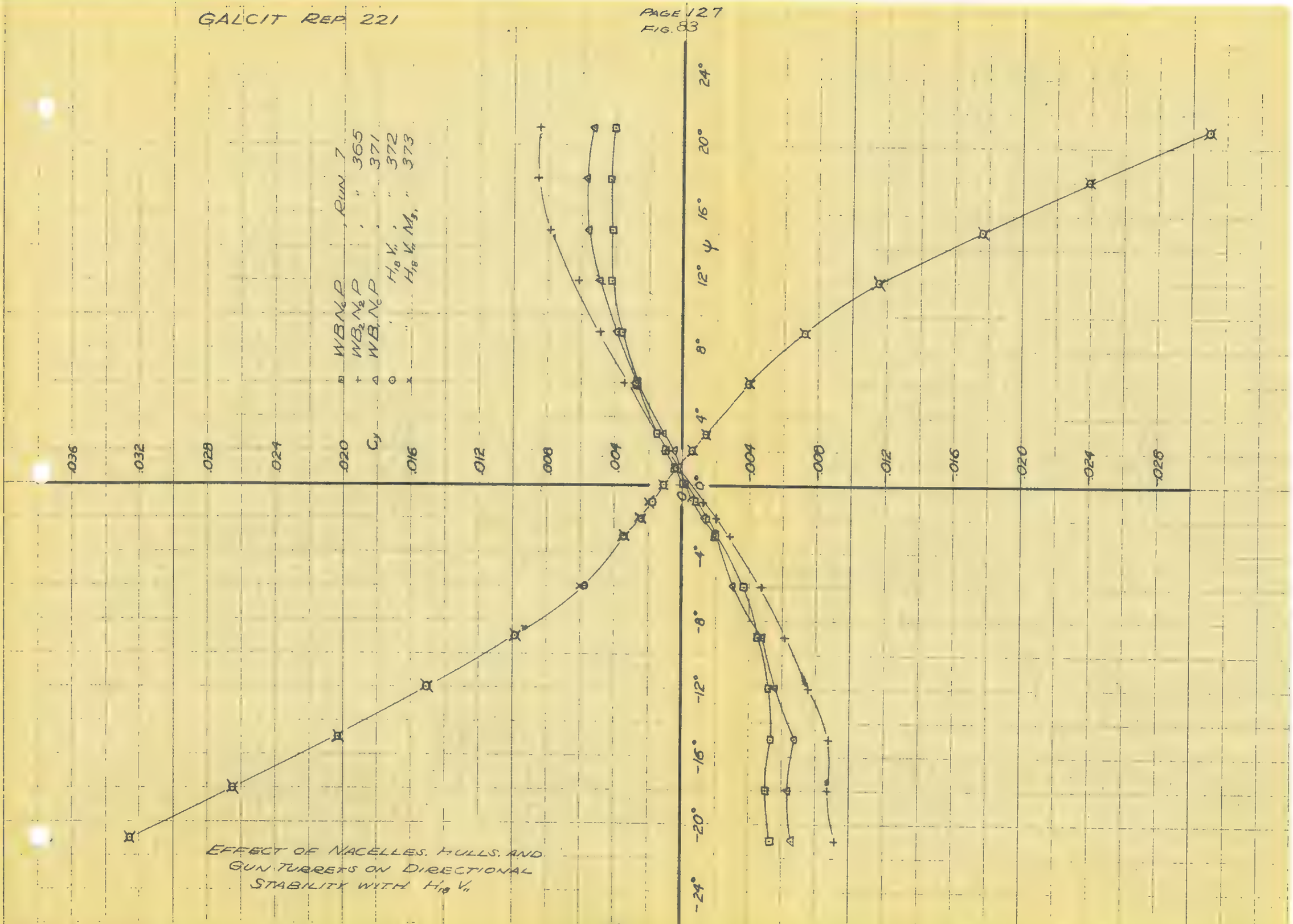


EFFECTS OF VARIOUS TAIL COMPONENTS IN H_2V_2V ON DIRECTIONAL STABILITY



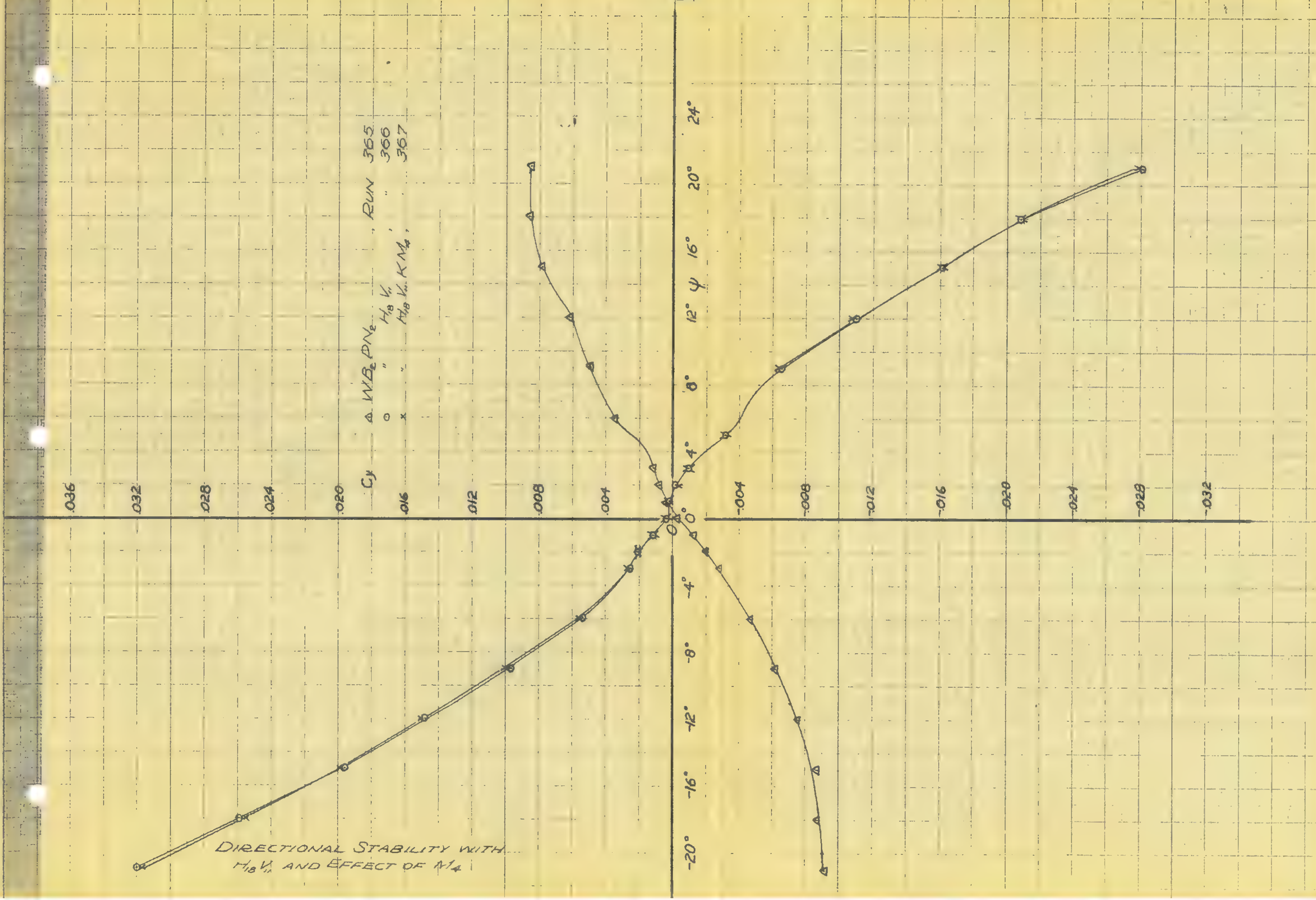
EFFECT OF VARIOUS TAIL COMPONENTS IN H_3V_3 ON DIRECTIONAL STABILITY


⊙ WBNPH3V3 RUN 1
△ WBNPH3V RUN 6
x WBNPH3 RUN 5
• WBNP RUN 7
008
012
016
020
024
028
032
036
040



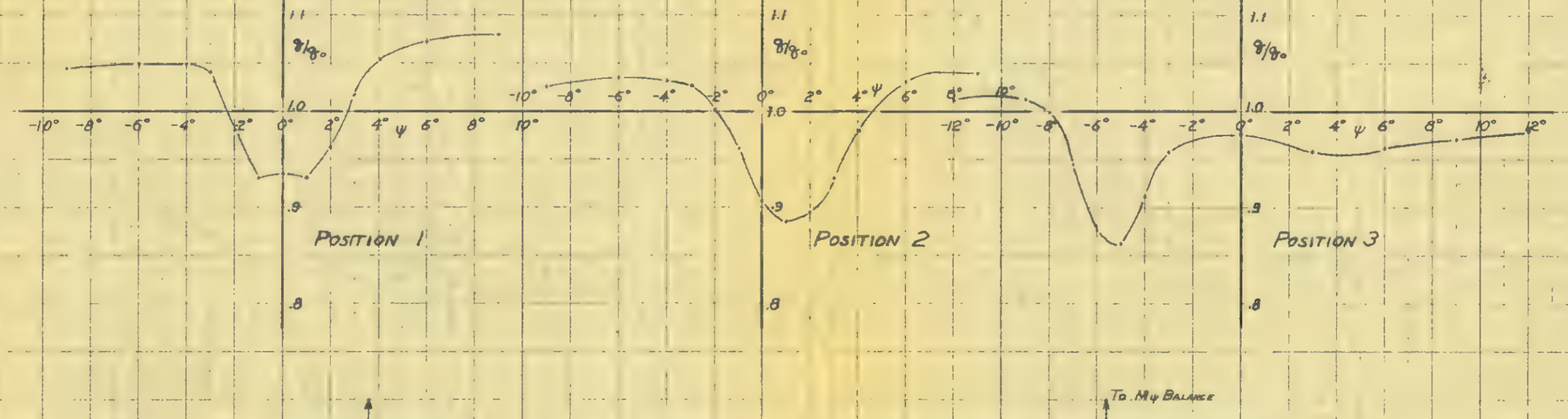
EFFECT OF NACELLES, HULLS, AND GUN TURRETS ON DIRECTIONAL STABILITY WITH H_{18} V_{11}

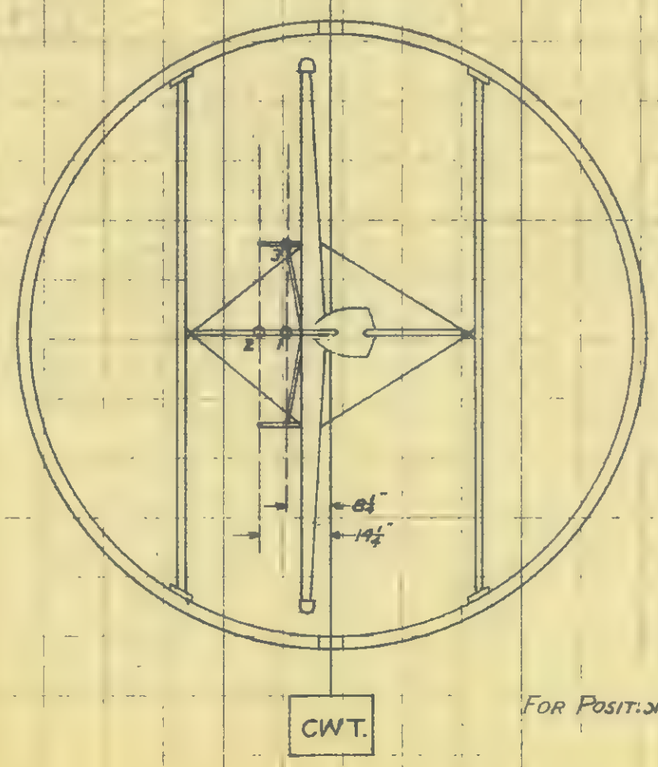
FIG. 84

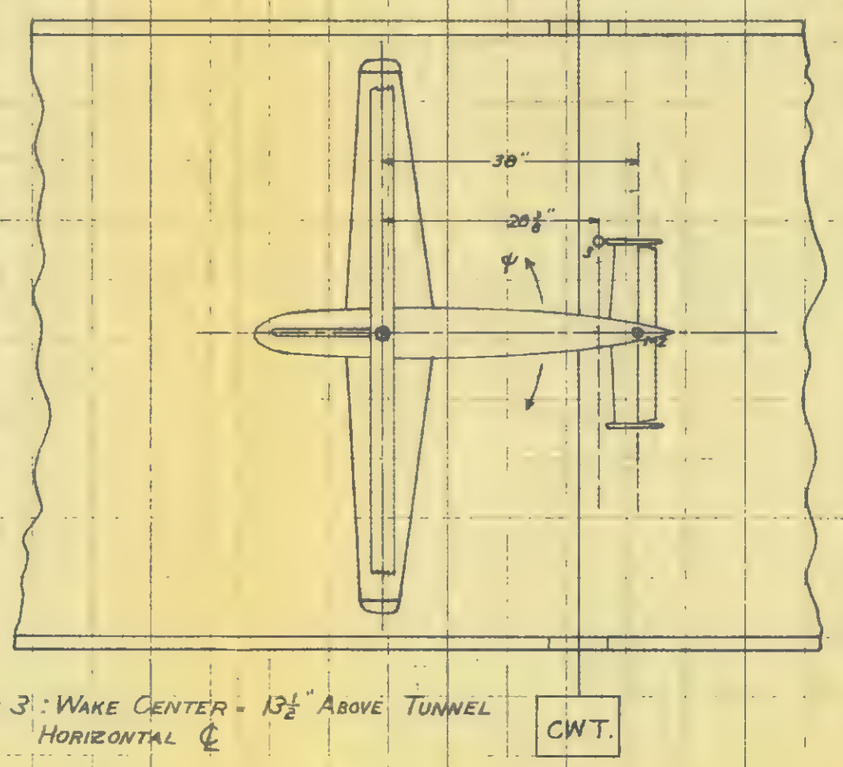


DIRECTIONAL STABILITY WITH $H_{18} V_1$, AND EFFECT OF M_4

FIG. 85

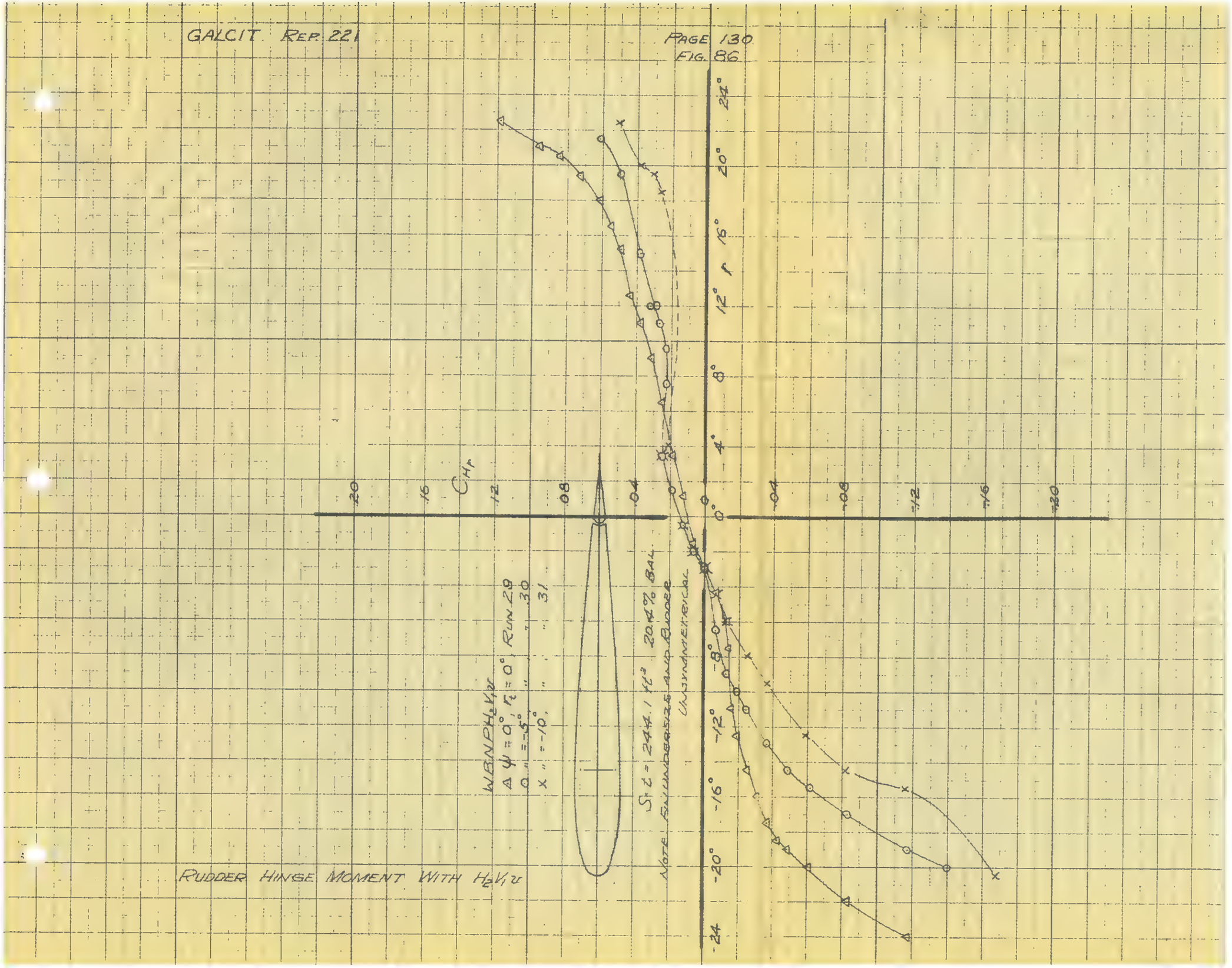






FOR POSITION 3 : WAKE CENTER - 13½" ABOVE TUNNEL HORIZONTAL ℄

YAW RIGGING STRUTS AND WIRE. WAKES IN THE VICINITY OF THE EMPENNAGE



RUDDER HINGE MOMENT WITH H_2V_1r

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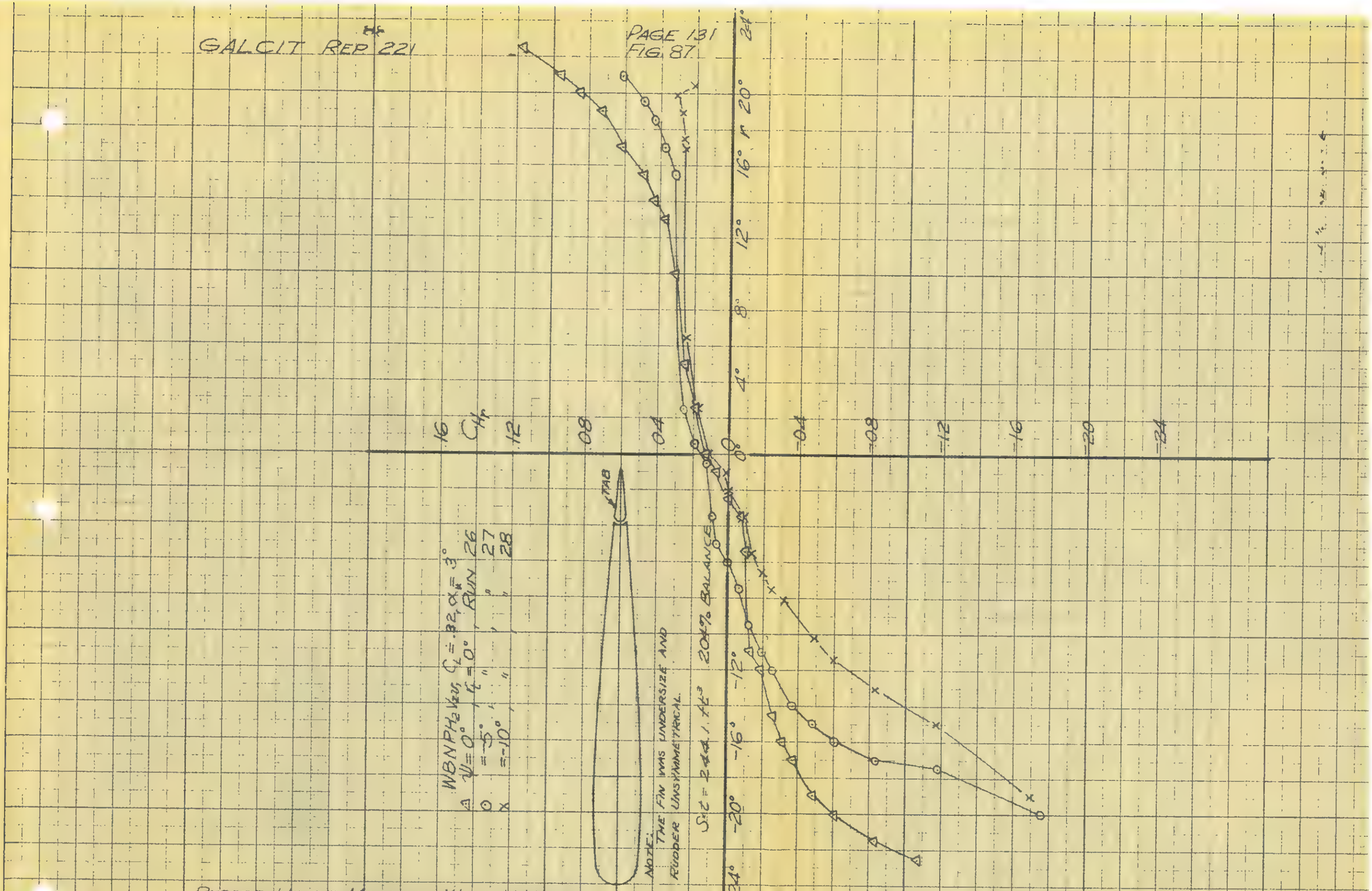
FIG. 87



RUDDER HINGE MOMENT WITH $H_2 V_2$ 0°

NOTE: THE FIN WAS UNDERSIZE AND ROUGH UNINTENTIONALLY

KARMAN-KEY M_{hinge} = 3.0°
$\Box$ α_w = 2.5° δ_e = 0° RUN 262
$\triangle$ " = 0° " 263
+ " = -2.5° " 264
○ " = -5° " 265
◇ " = -7.5° " 266
× " = -10° " 267
* " = -15° " 269
▽ FREE " 270
S_{ref} = 2442 FT^2
20.42 lb BALANCE

C_{h_δ}

C_{h_α}

C_{h_α}

C_{h_δ}

RUDDER HINGE MOMENT & EFFECTIVENESS & RUDDER FREE STABILITY WITH H_2V_2

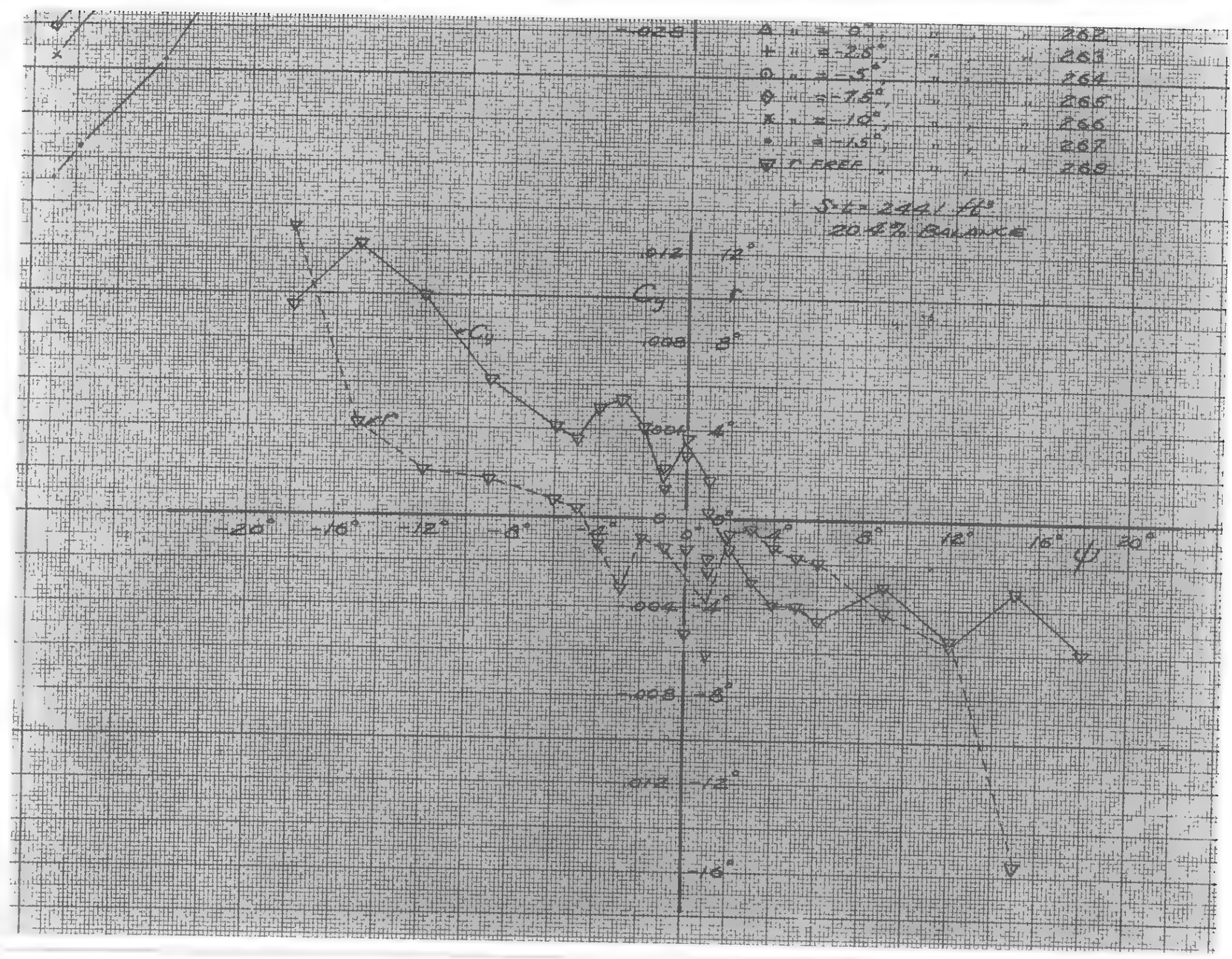

Δ α = 0°
+ α = 2.5°
○ α = 5°
◇ α = 7.5°
× α = 10°
• α = 15°
▽ Free
Σ = 244 / 42°
20-2% Balance
C_y
C_n
C_l
ψ
-.028
-.012
-.008
-.004
.004
.008
.012
.028
-20°
-16°
-12°
-8°
-4°
0°
4°
8°
12°
16°
20°

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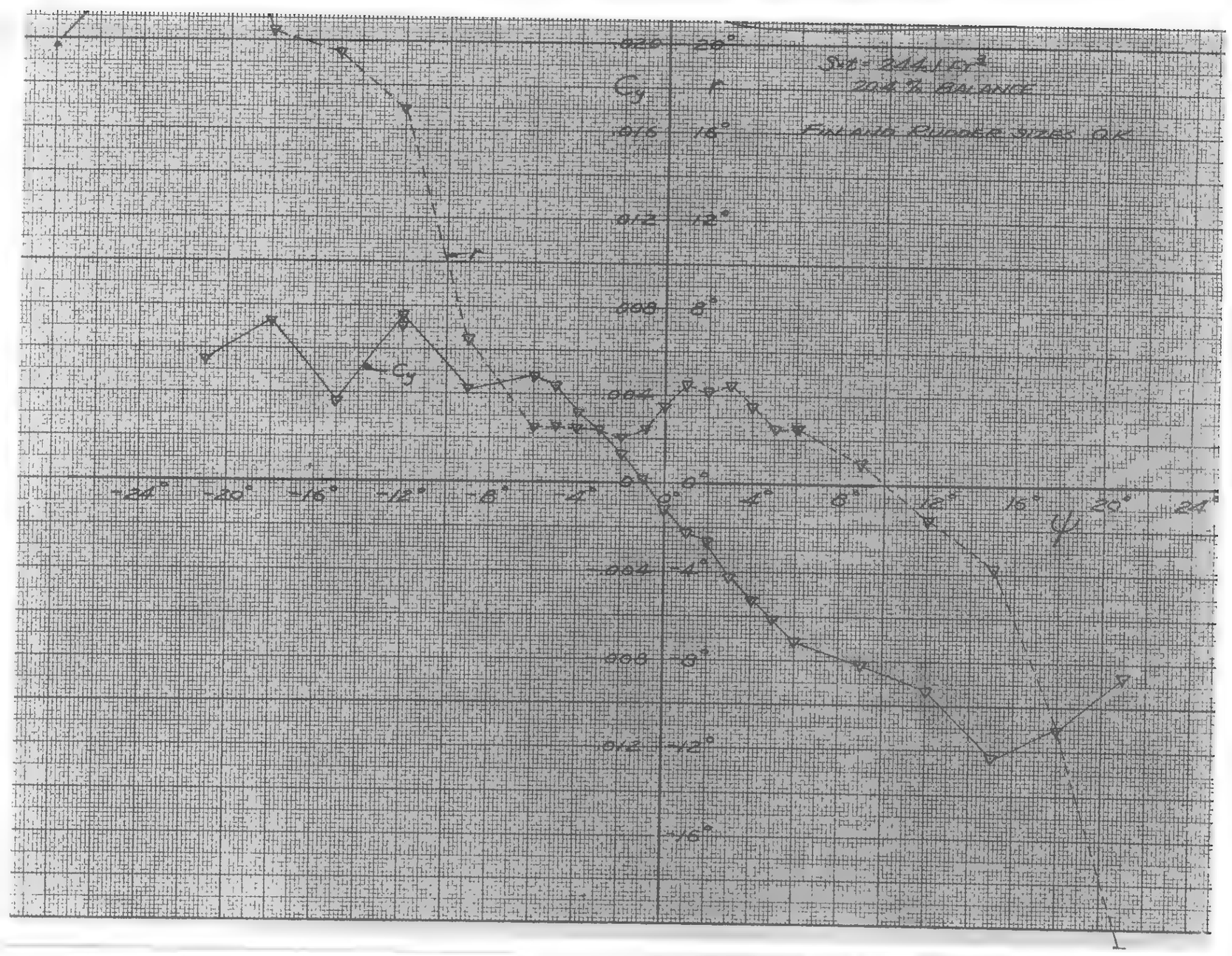
Fig 88

Rudder Hinge Moment and Effectiveness and Rudder Free Stability with $h_2 = \frac{1}{2}$"


C_y
C_y
ψ
S_W = 2.44 ft²
20% Balance
Full and Cooke size 0.4
.020
.016
.012
.008
.004
0
-.004
-.008
-.012
20°
16°
12°
8°
4°
0°
-4°
-8°
-12°
-16°
-24°
-20°
-16°
-12°
-8°
-4°
0°
4°
8°
12°
16°
20°
24°

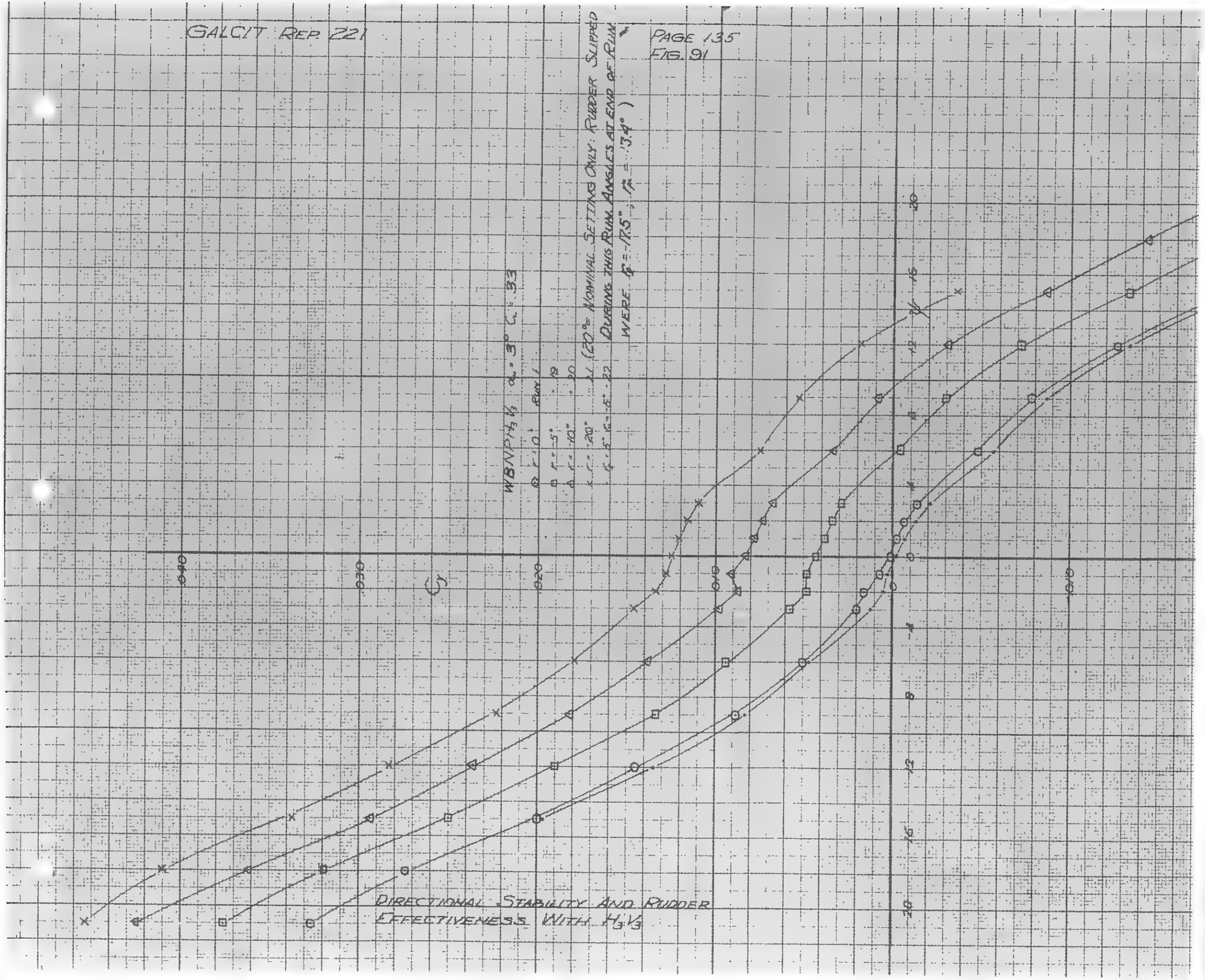
RUDDER HINGE MOMENT WITH H_3V_3

WBFNH3V3

	γ_F = -10°	γ_F = 0°	RUN #
×	-5°		12
○	0°		13
△	5°		14
□	10°		15

(RIGHT RUDDER ONLY)

S_F = 1448 ft² (ONE) 1837 BAL


WBNP H3 V3 α=-3° 2, 33
δr = -5°
δr = -10°
δr = -20°
(δr = Nominal Setting Only. Rudder Slipped During This Run. Angles at End of Run Were δr = -17.5°, δr = -34°)
Cy
Cn
Directional Stability And Rudder Effectiveness With H3 V3

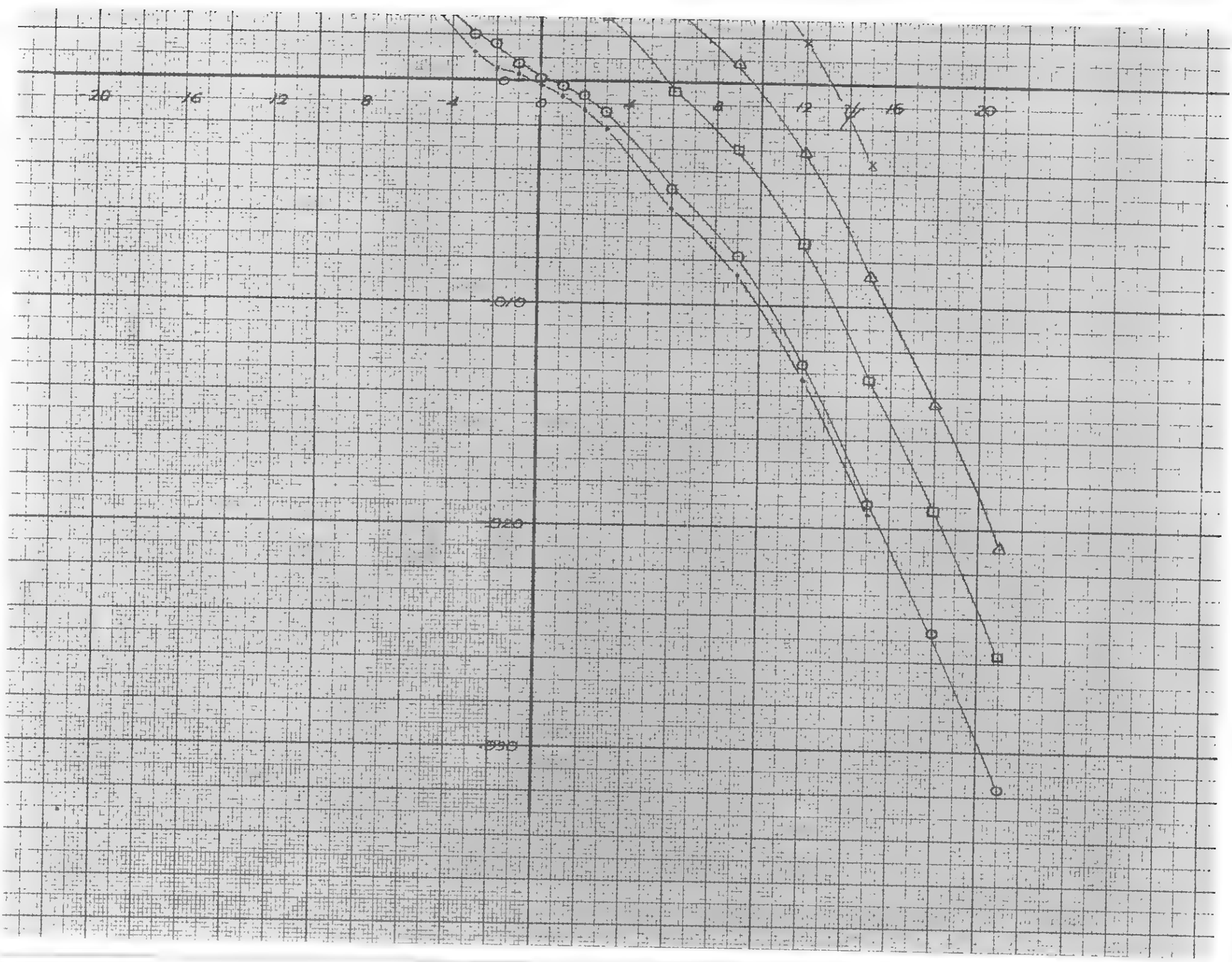

20
16
12
8
4
0
4
8
12
16
20
-010
-020
-030

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FIG 92

RUDDER HINGE MOMENT & EFFECTIVENESS & RUDDER-FREE STABILITY WITH $H_1 V_3$

C_{H_1}

C_Y

$C_{Y'}$

$C_{Y''}$

C_{H_1} vs C_Y

$\psi = 2.5°$, $\eta = 0°$, RUN 273
$\psi = 0°$, " 274
$\psi = -2.5°$, " 275
$\psi = -5°$, " 276
$\psi = -7.5°$, " 277
$\psi = -10°$, " 278
$\psi = -15°$, " 279
RUDDER FREE " 280

α: 20°, 16°, 12°, 8°, 4°, 0°, -4°, -8°, -12°, -16°, -20°, -28°

C_{H_1}: .02, 0, -.04, -.08, -.12, -.16, -.20, -.24, -.28, -.32, -.36

C_Y: .8, .6, .4, .2, 0, -.2, -.4, -.6, -.8, -1.0, -1.2

S.2 - 2890 cm² (Model Two)
18.37% BALANCE

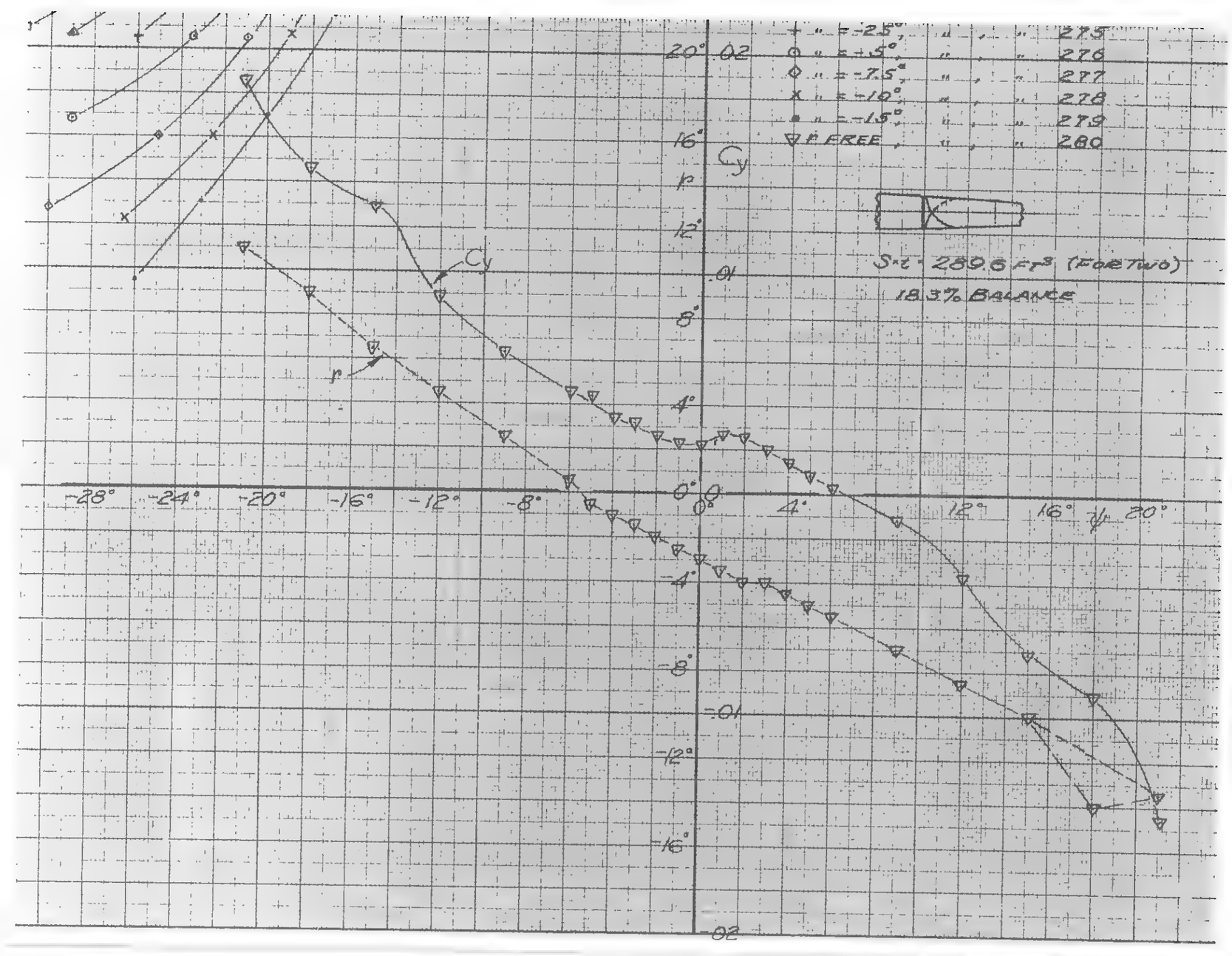
+ " ε=-2.5°, " " " 275
○ " ε=-5°, " " " 276
◇ " ε=-7.5°, " " " 277
X " ε=-10°, " " " 278
● " ε=-15°, " " " 279
▽ FREE " " " 280
S·t = 289.6 Ft² (FOR TWO)
18.3% BALANCE
Cy
p
20°
16°
12°
8°
4°
0°
-4°
-8°
-12°
-16°
.02
.01
-.01
-.02
-28°
-24°
-20°
-16°
-12°
-8°
4°
12°
16°
20°

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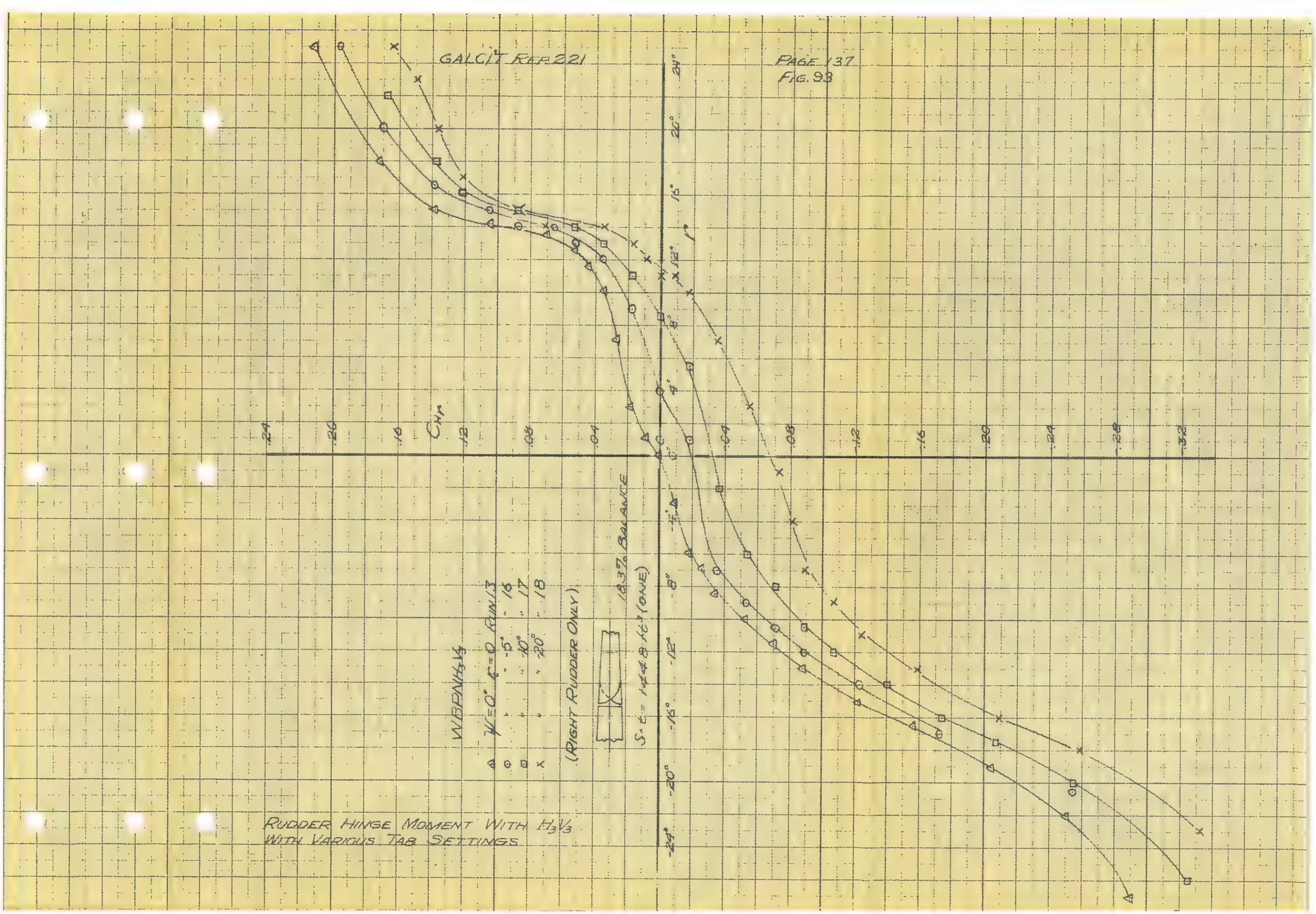
FIG. 93



RUDDER HINGE MOMENT WITH H_3V_3
WITH VARIOUS TAB SETTINGS

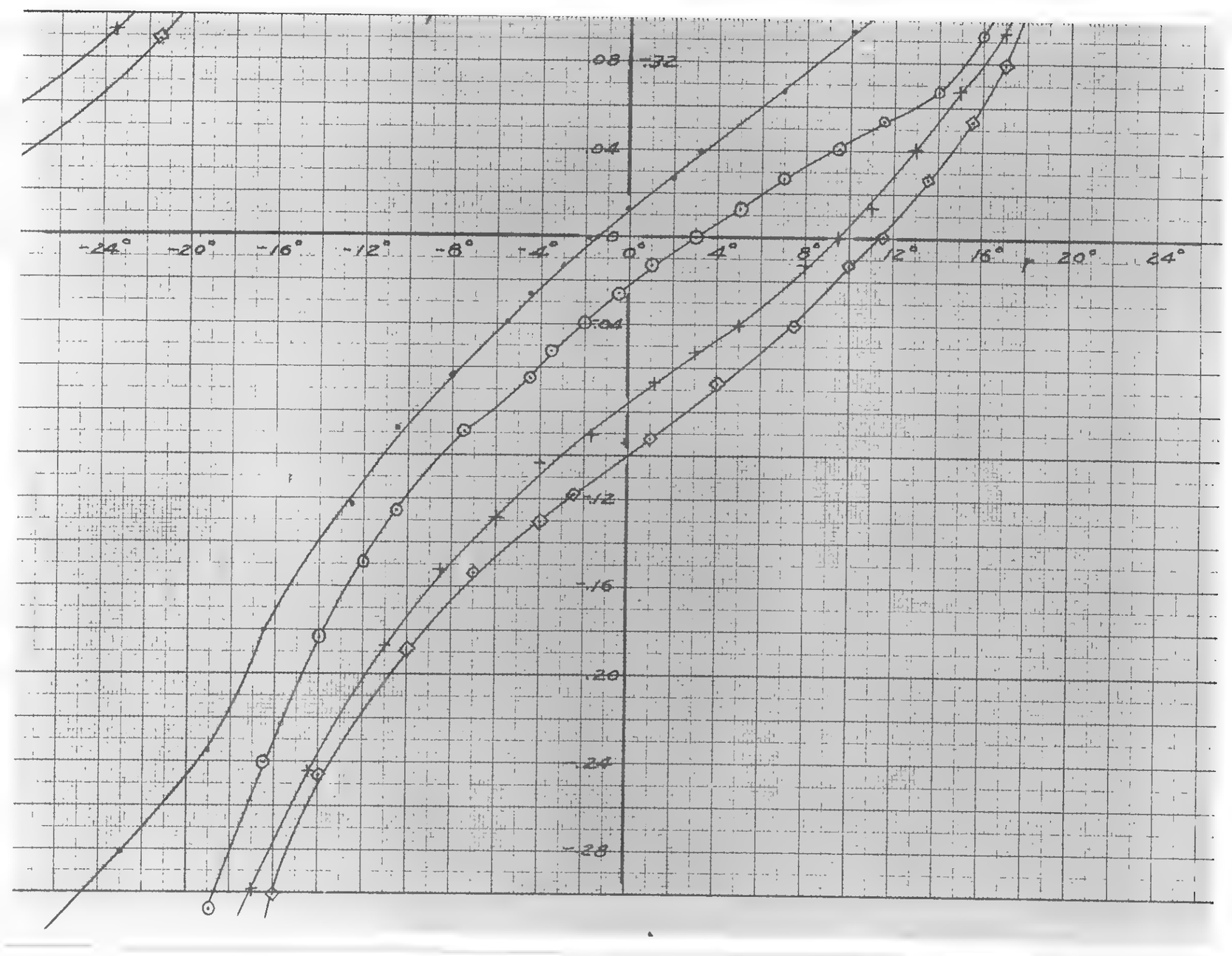
WBPN6 H16 V3 α_w = 3.0°

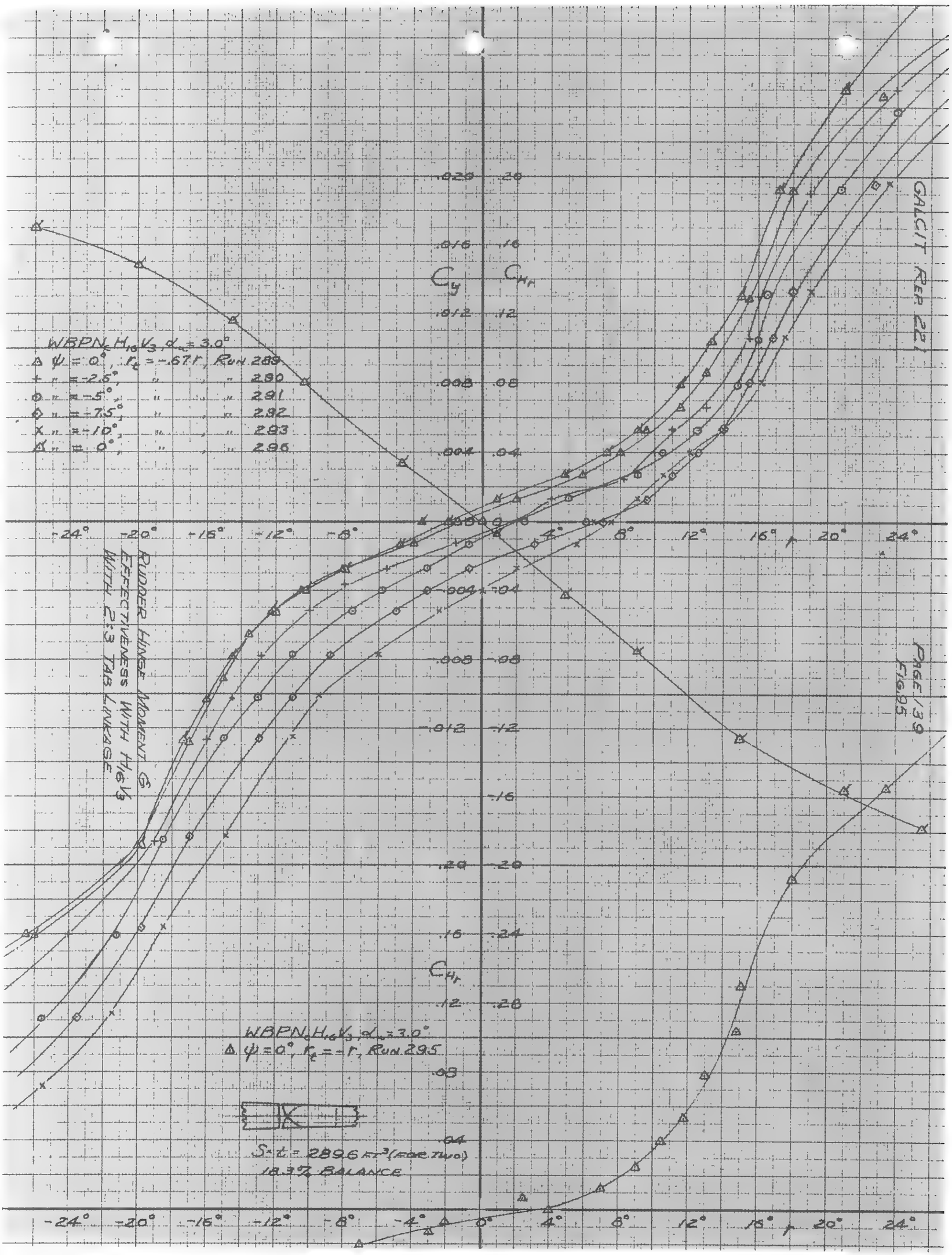
- ● i_t = 12° Runs 286, 287
- ○ " = 0° " 274, 278
- + " = -10° " 284, 285
- ◇ " = -20° " 282, 283

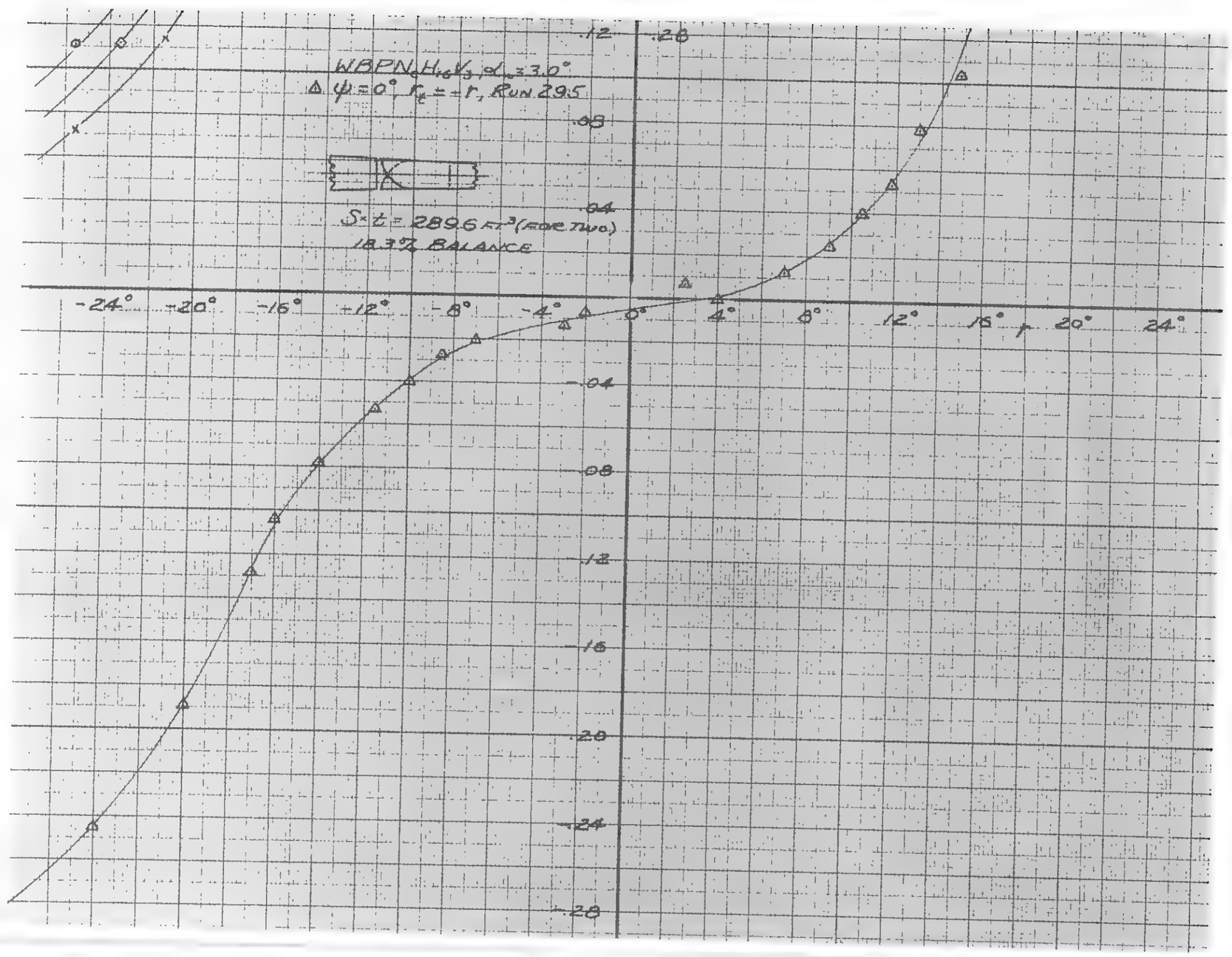
S.F. = 2801 (see text)

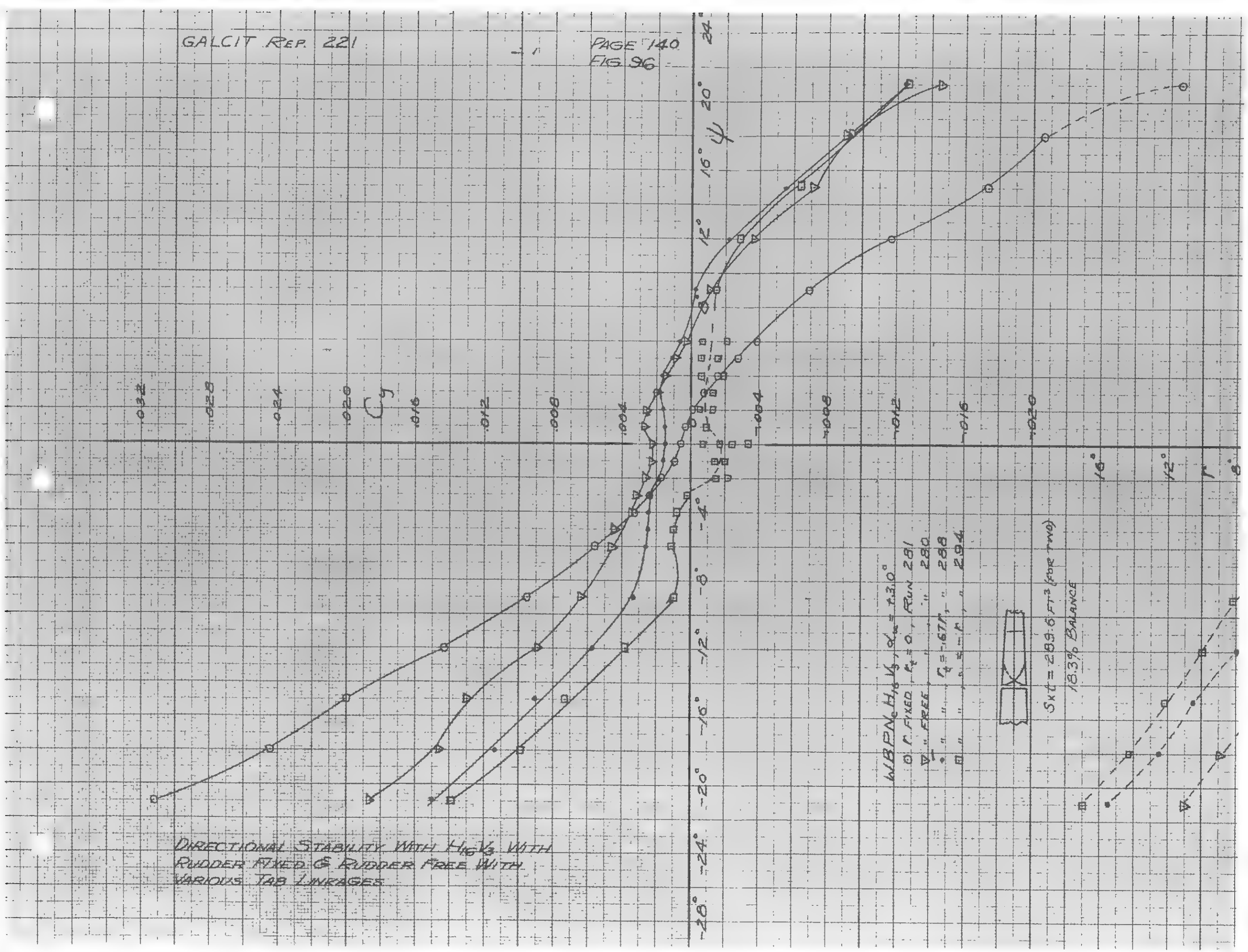
18.3% Balance

RUDDER HINGE MOMENT WITH $H_{16}V_3$
WITH VARIOUS TAB SETTINGS

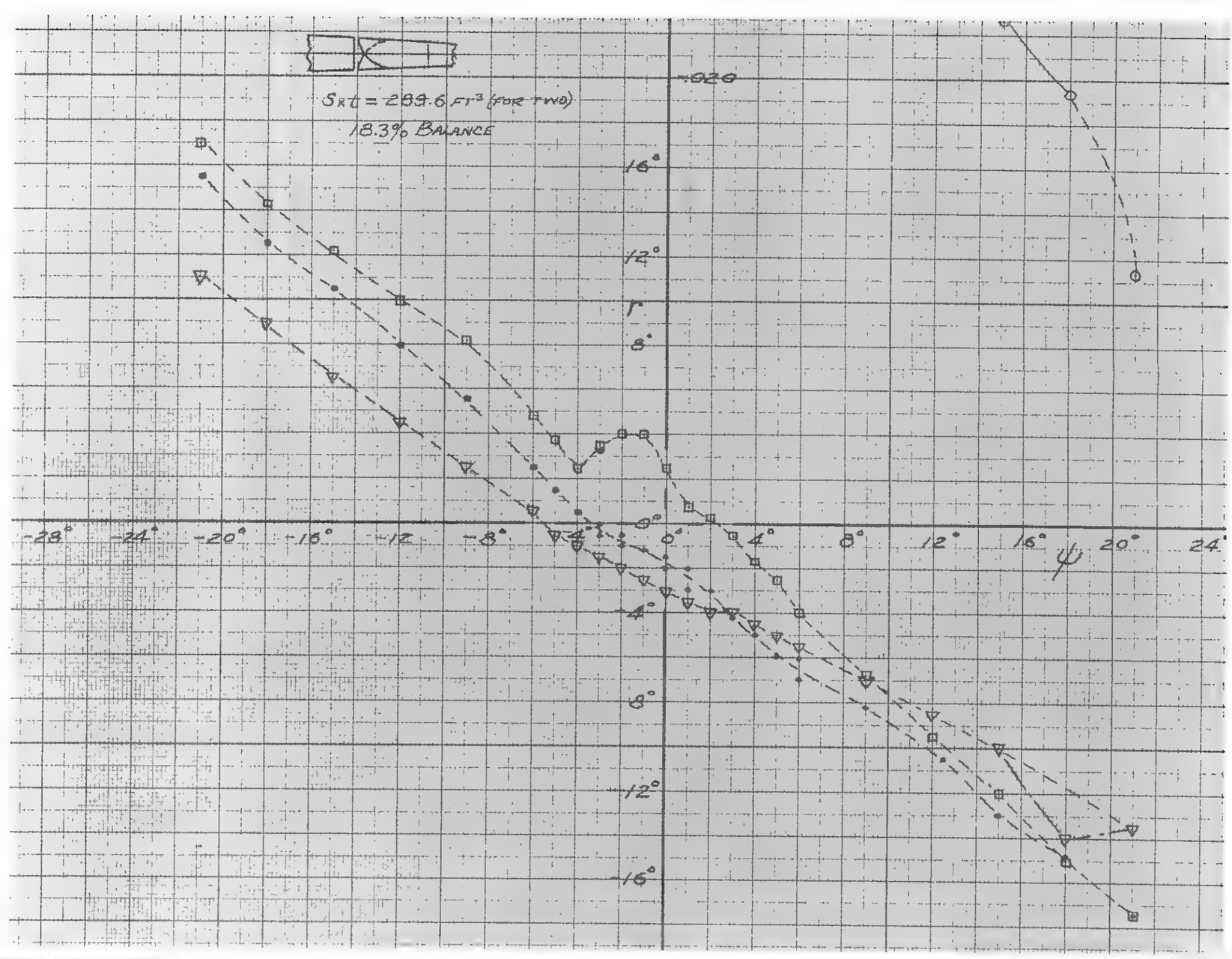

-24°
-20°
-16°
-12°
-8°
-4°
0°
4°
8°
12°
16°
20°
24°
-.08
-.32
-.04
-.04
-.12
-.16
-.20
-.24
-.28

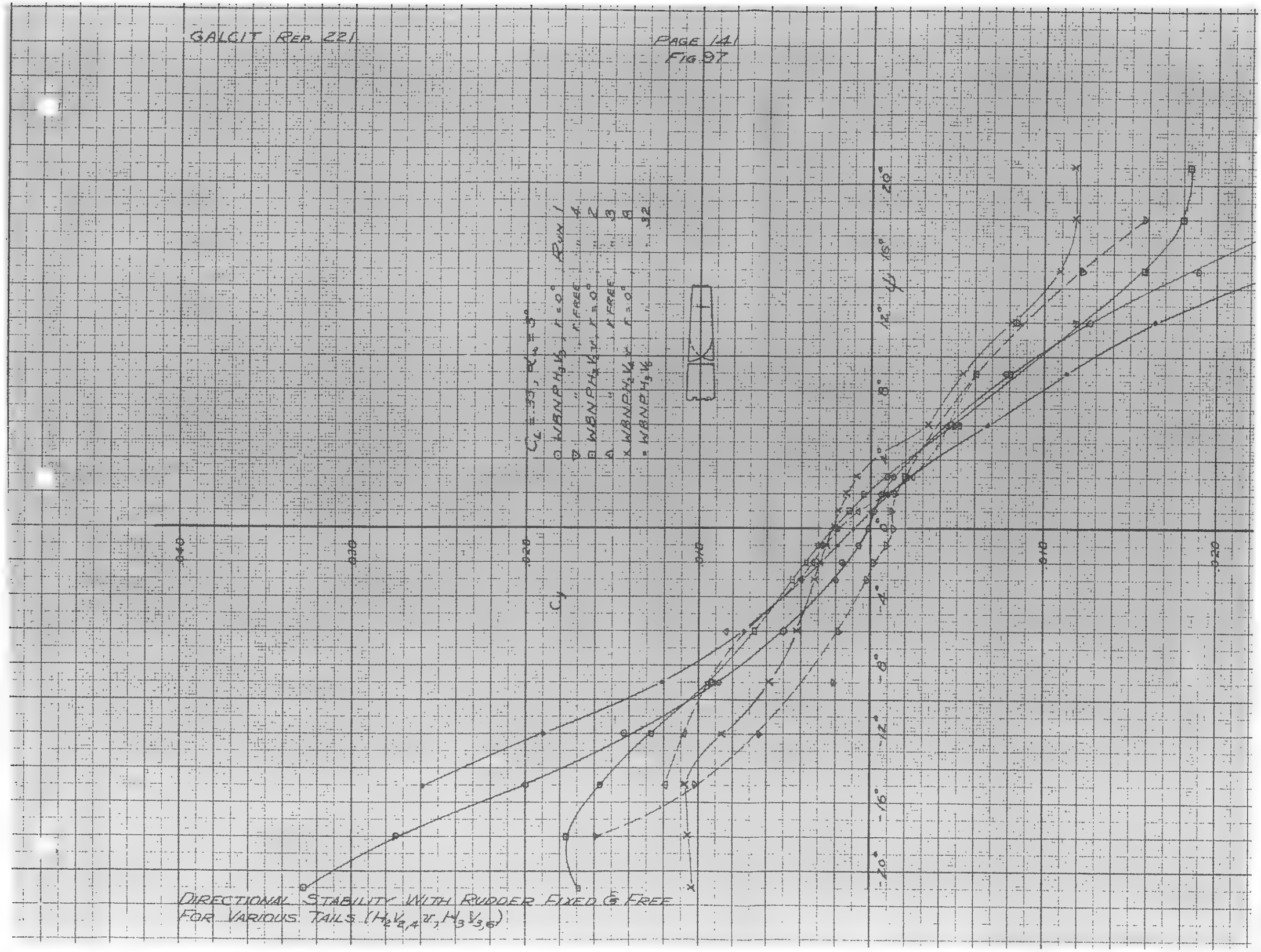

RUDDER HINGE MOMENT & EFFECTIVENESS WITH HEAVY WITH 2:3 TAB LINKAGE
C_y
C_{H_r}
$WBPN_6H_{10}V_3$, $\alpha_w = 3.0°$
$\Delta\ \psi = 0°$, $\tau_e = -.67\tau$, Run 289
$+$ " $= -2.5°$, " " " 290
$\circ$ " $= -5°$, " " " 291
$\diamond$ " $= -7.5°$, " " " 292
$\times$ " $= -10°$, " " " 293
Δ " $= 0°$, " " " 296
$WBPN_6H_6V_3$, $\alpha_w = 3.0°$
$\Delta\ \psi = 0°$, $\tau_e = -\tau$, Run 295
$S \cdot \ell = 2896\ in^3$ (FOR $\tau_{1/0}$)
18.3% BALANCE


WBPN$_4$H$_{16}$V$_3$, α_w = 3.0°
△ ψ = 0°, r_t = -1, RUN 29.5
S×ℓ = 289.6 in^3 (FOR TWO)
18.3% BALANCE
.12
.08
.04
-.04
-.08
-.12
-.16
-.20
-.24
-.28
-24°
-20°
-16°
-12°
-8°
-4°
0°
4°
8°
12°
16°
20°
24°

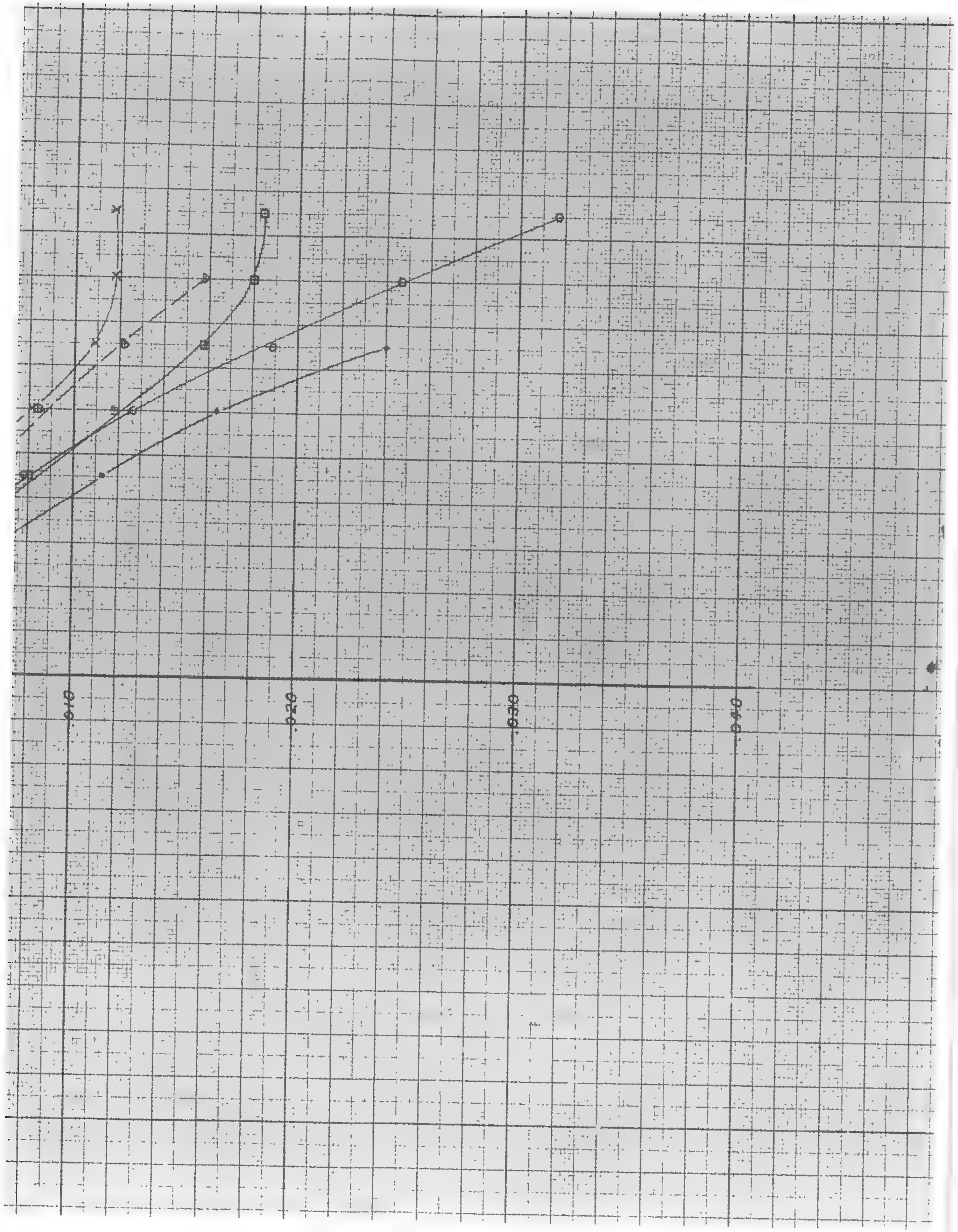


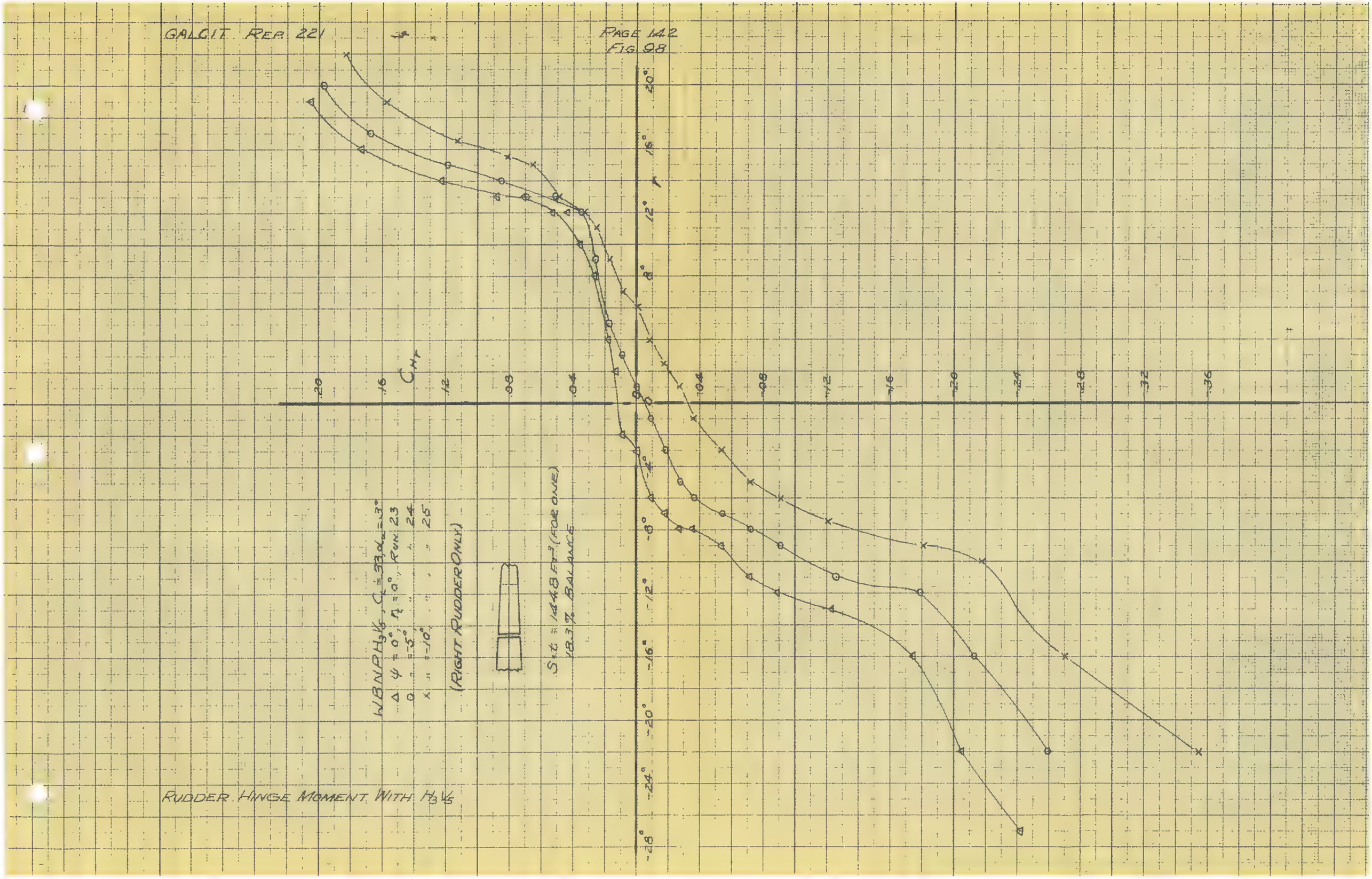
DIRECTIONAL STABILITY WITH $H_{16}V_3$ WITH RUDDER FIXED & RUDDER FREE WITH VARIOUS TAB LINKAGES


SxL = 289.6 FT³ (FOR TWO)
18.3% BALANCE
-.020
16°
12°
8°
4°
0°
-4°
-8°
-12°
-16°
-28°
-24°
-20°
-16°
-12
-8°
-4°
0°
4°
8°
12°
16°
20°
24°
Ψ



DIRECTIONAL STABILITY WITH RUDDER FIXED & FREE FOR VARIOUS TAILS ($H_2V_{2.4}$ $H_3V_{3.6}$)


.010
.020
.030
.040



RUDDER HINGE MOMENT WITH $H_3 V_5$

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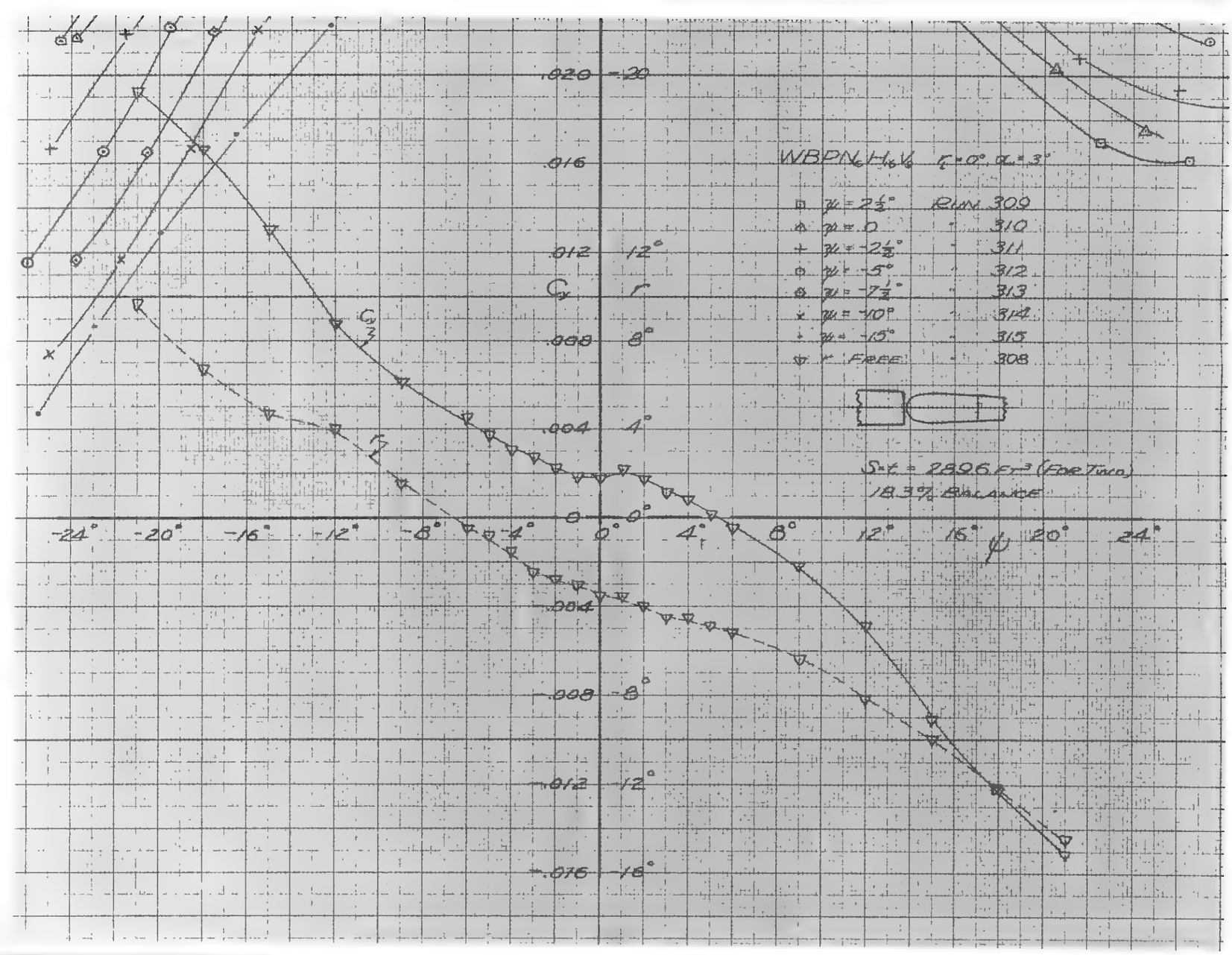
FIG 99

RUDDER HINGE MOMENTS AND EFFECTIVENESS AND RUDDER-FREE STABILITY WITH H_{16} V_D

WING 4414 δ_{w_0} = -3.3°

□	δ_w = -25° RUN 300
△	δ_w = 0 310
+	δ_w = -25° 311
○	δ_w = -5° 312
◇	δ_w = -22° 313
×	δ_w = -10° 314
·	δ_w = -10° 315


WBPN6 H16 V6 i_t = 0° α = 3°
□ γ = 2½° Run 309
◇ γ = 0 " 310
+ γ = -2½° " 311
○ γ = -5° " 312
⊗ γ = -7½° " 313
× γ = -10° " 314
· γ = -15° " 315
▽ Free " 308
S = 2.96 Ft² (Fore Two)
18.3% Balance
C_Y
C_Z
C_l
ψ
.020
.016
.012
.008
.004
-.004
-.008
-.012
-.016
-20
12°
8°
4°
0°
-8°
-12°
-16°
-24°
-20°
-16°
-12°
-8°
-4°
0°
4°
8°
12°
16°
20°
24°

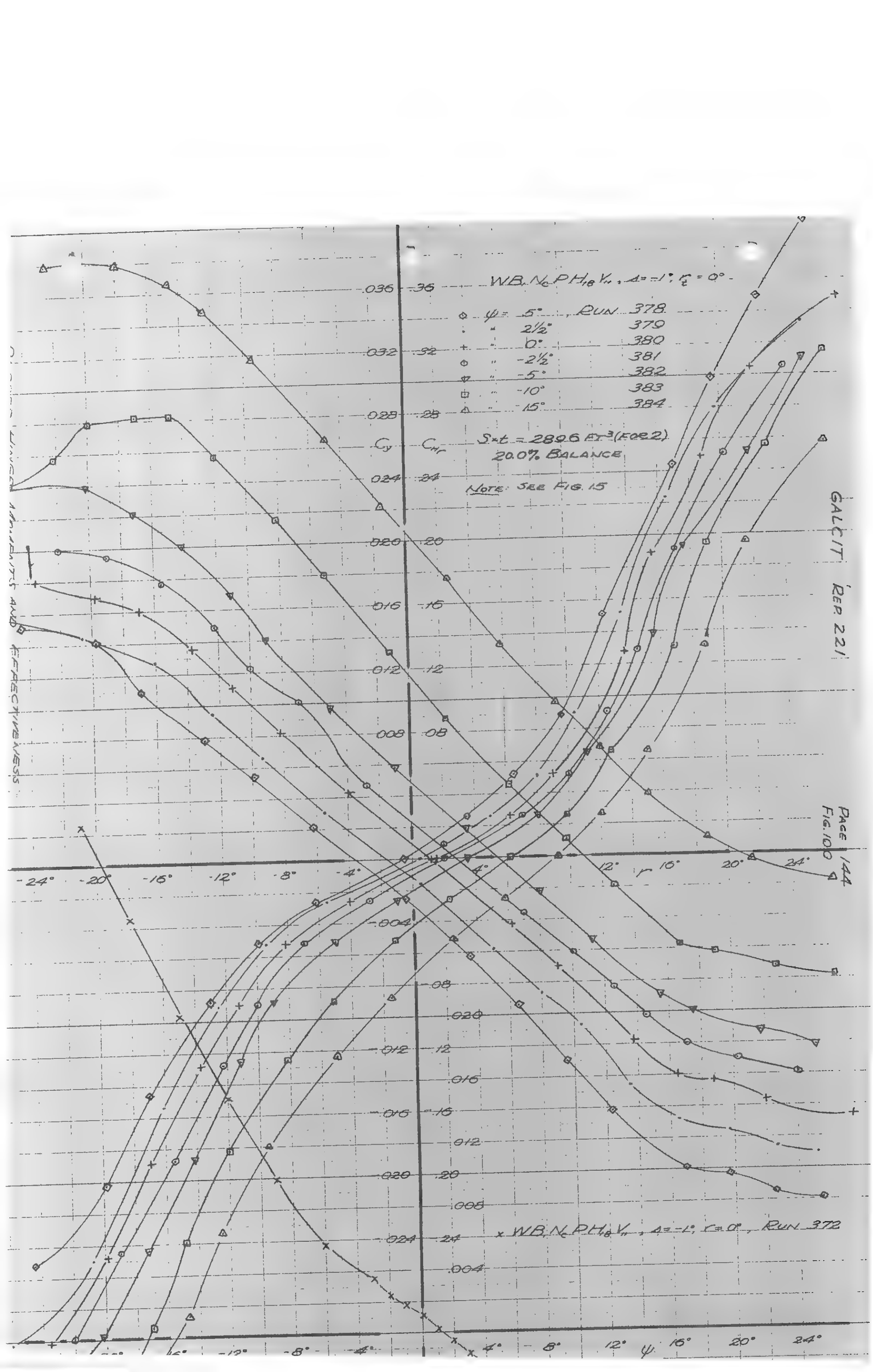

W.B. N.C. P.H.18 V.. A=-1; Γ=0°
ψ= -5° RUN 378
" 2½° 379
" 0° 380
" -2½° 381
" -5° 382
" -10° 383
" -15° 384
S.t = 2896 Ft³ (FOR 2)
20.0% BALANCE
NOTE SEE FIG. 15
Cy
Cn_r
ψ
Γ
× W.B. N.C. P.H.18 V.. A=-1; Γ=0°, RUN 372
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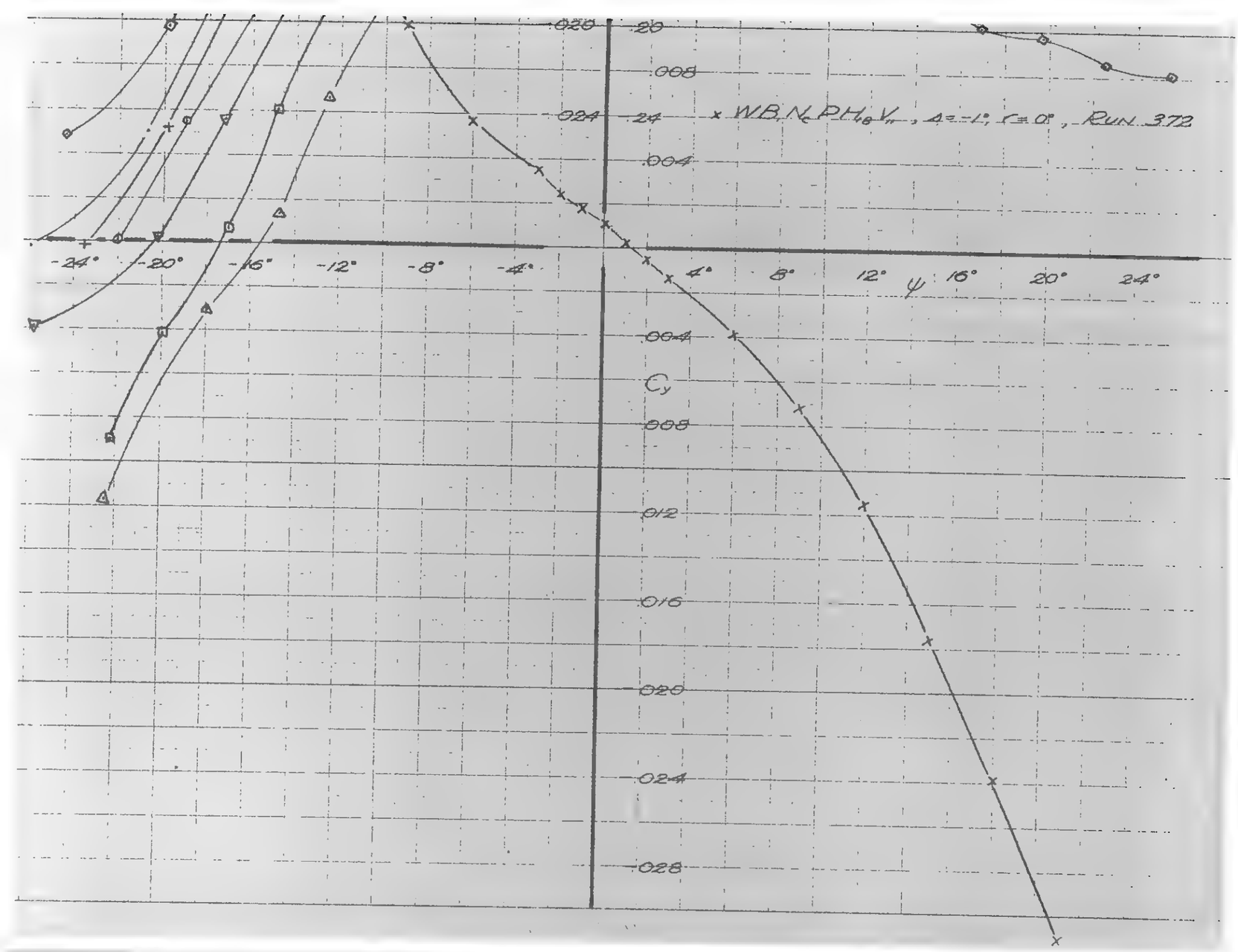
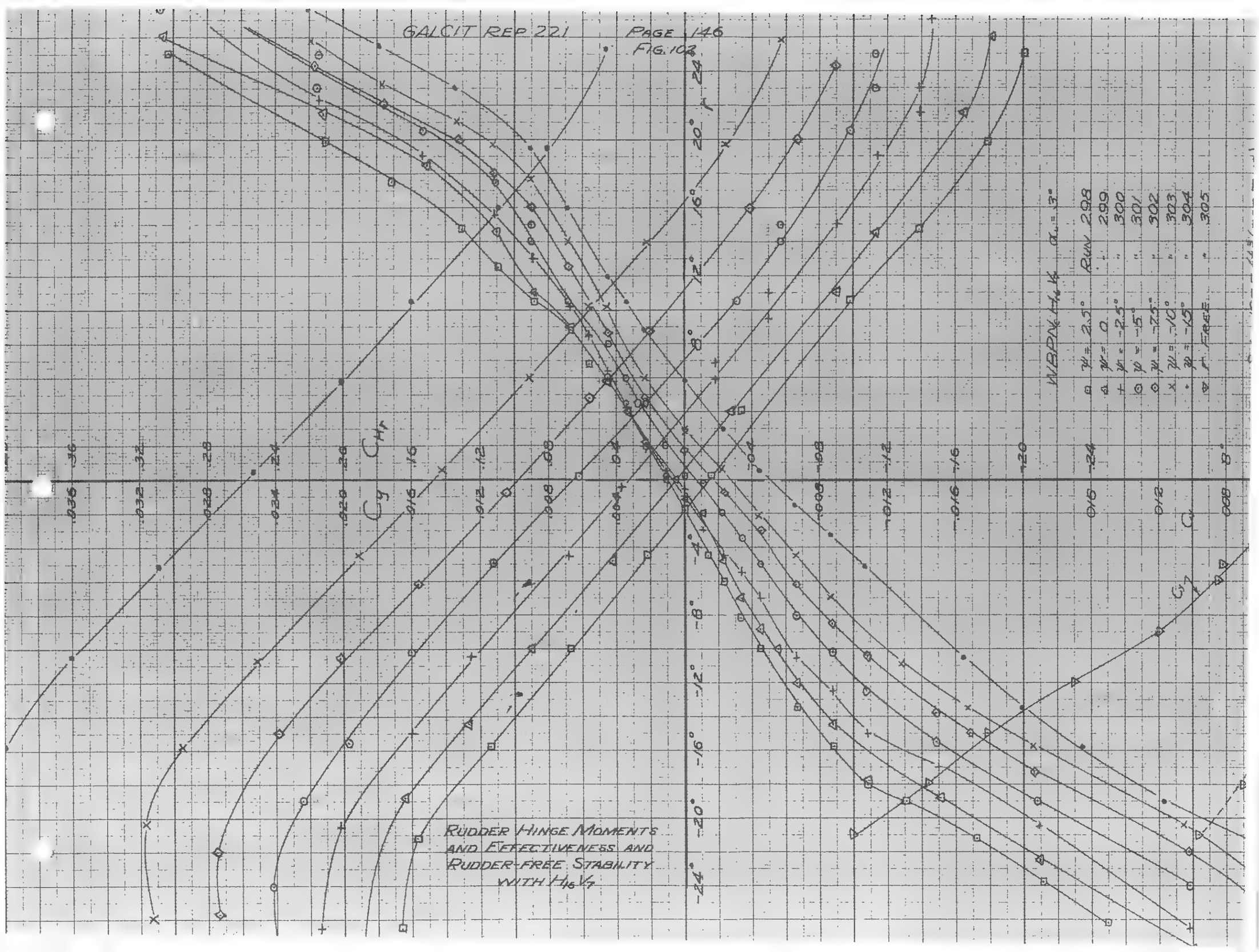
FIG. 100
DIRECTIONAL DAMPING AND EFFECTIVENESS


× WB, N, PH, V, , Δ=-1°, r=0° , RUN 372
-24°
-20°
-16°
-12°
-8°
-4°
4°
8°
12°
ψ
16°
20°
24°
Cy
.020
.016
.012
.008
.004
.024
.028

RUDDER HINGE MOMENTS AND
TAB EFFECTIVENESS WITH $H_{1/8}$ V_{11}



RUDDER HINGE MOMENTS AND EFFECTIVENESS AND RUDDER-FREE STABILITY WITH $H_{16}V_7$

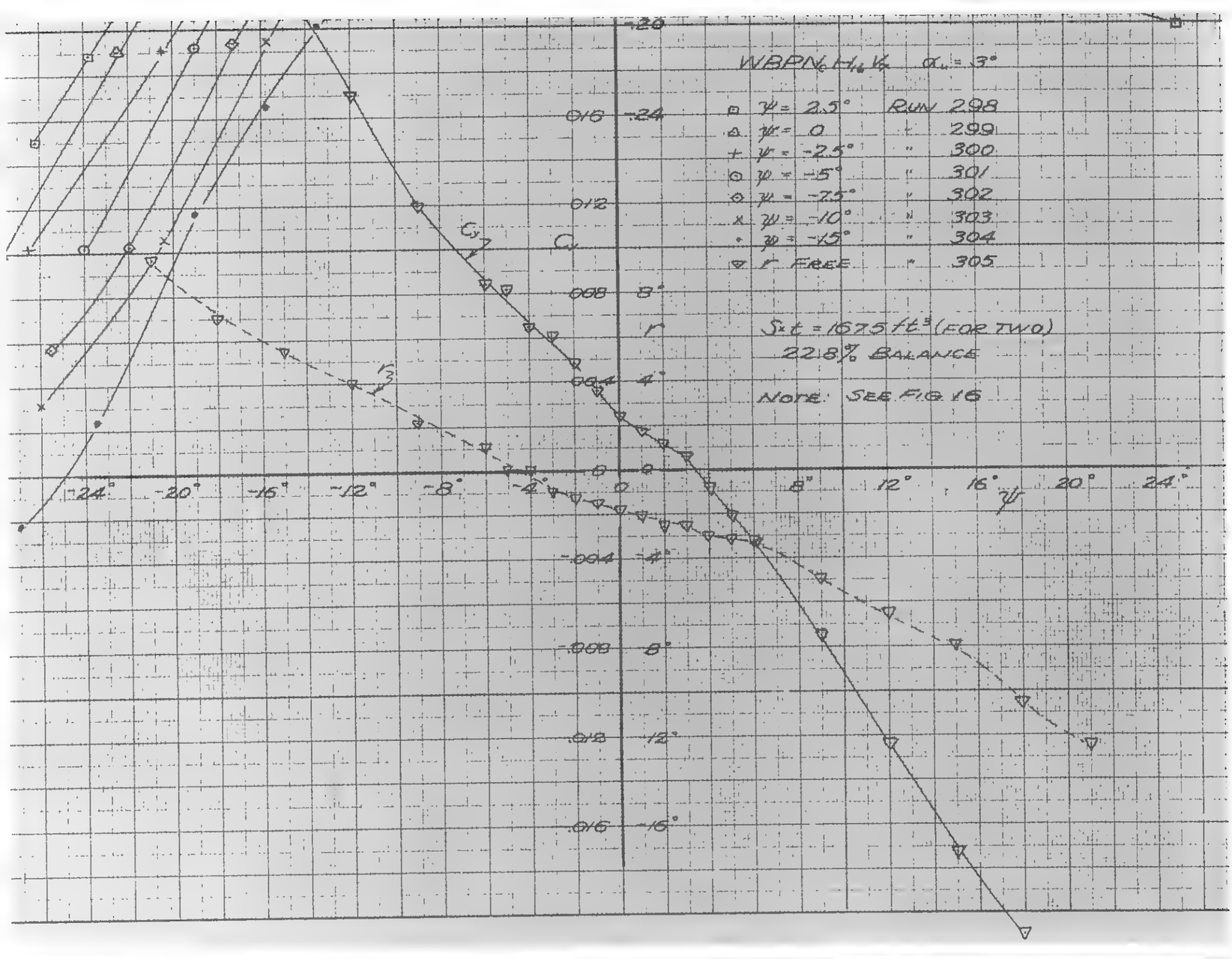

WBPN6 H1/6 V4 $\alpha_w = 3°$
□ $\psi = 2.5°$ RUN 298
△ $\psi = 0$ " 299
+ $\psi = -2.5°$ " 300
○ $\psi = -5°$ " 301
◇ $\psi = -7.5°$ " 302
x $\psi = -10°$ " 303
· $\psi = -15°$ " 304
▽ r FREE " 305
$S \cdot t = 1675$ ft³ (FOR TWO)
22.8% BALANCE
NOTE: SEE FIG 16
C_y
C_n
r
ψ
-24°
-20°
-16°
-12°
-8°
-4°
0
8°
12°
16°
20°
24°
.016
.012
.008
.004
-.004
-.008
-.012
-.016
4°
-4°
-8°
-12°
-16°

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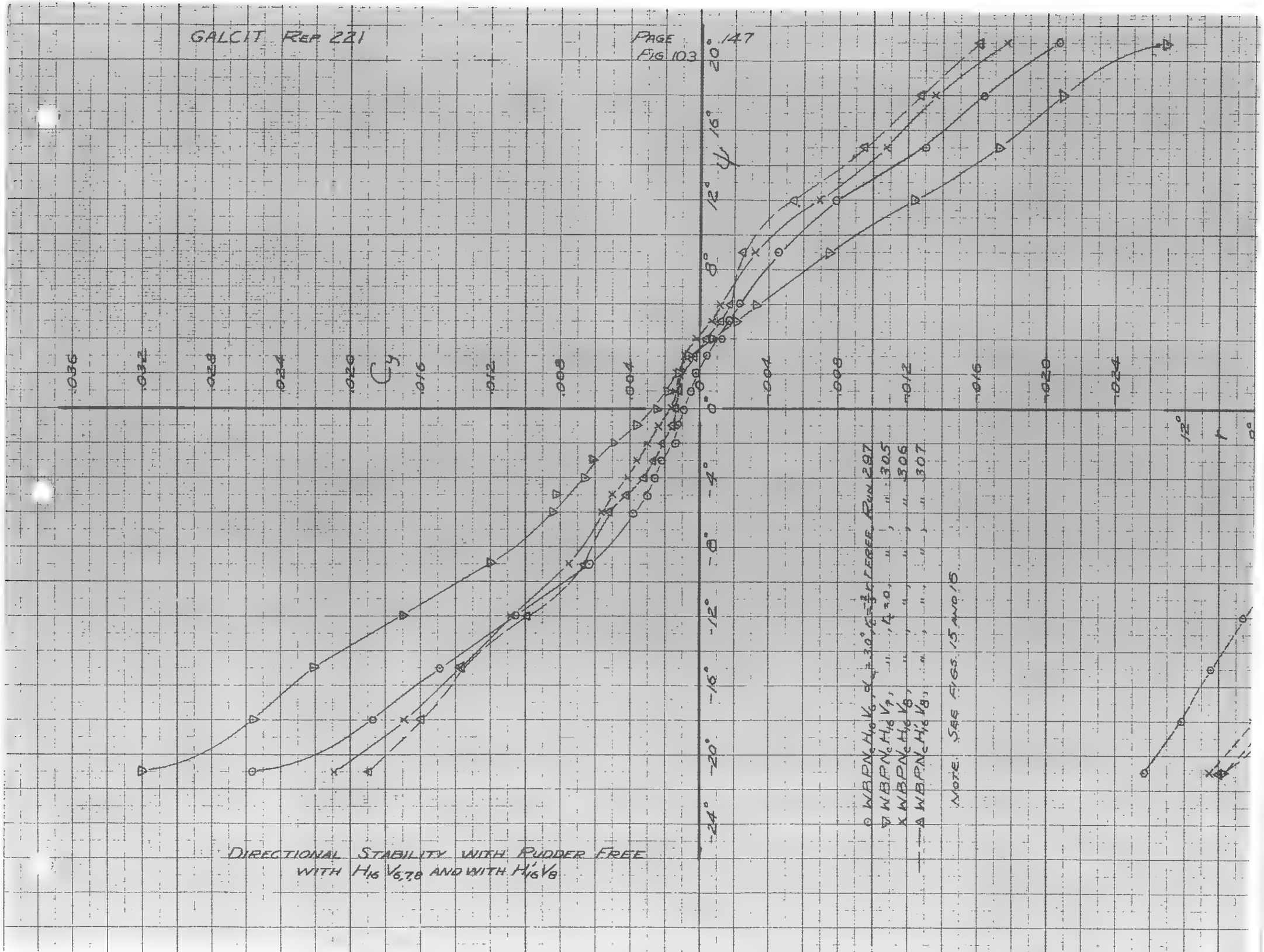
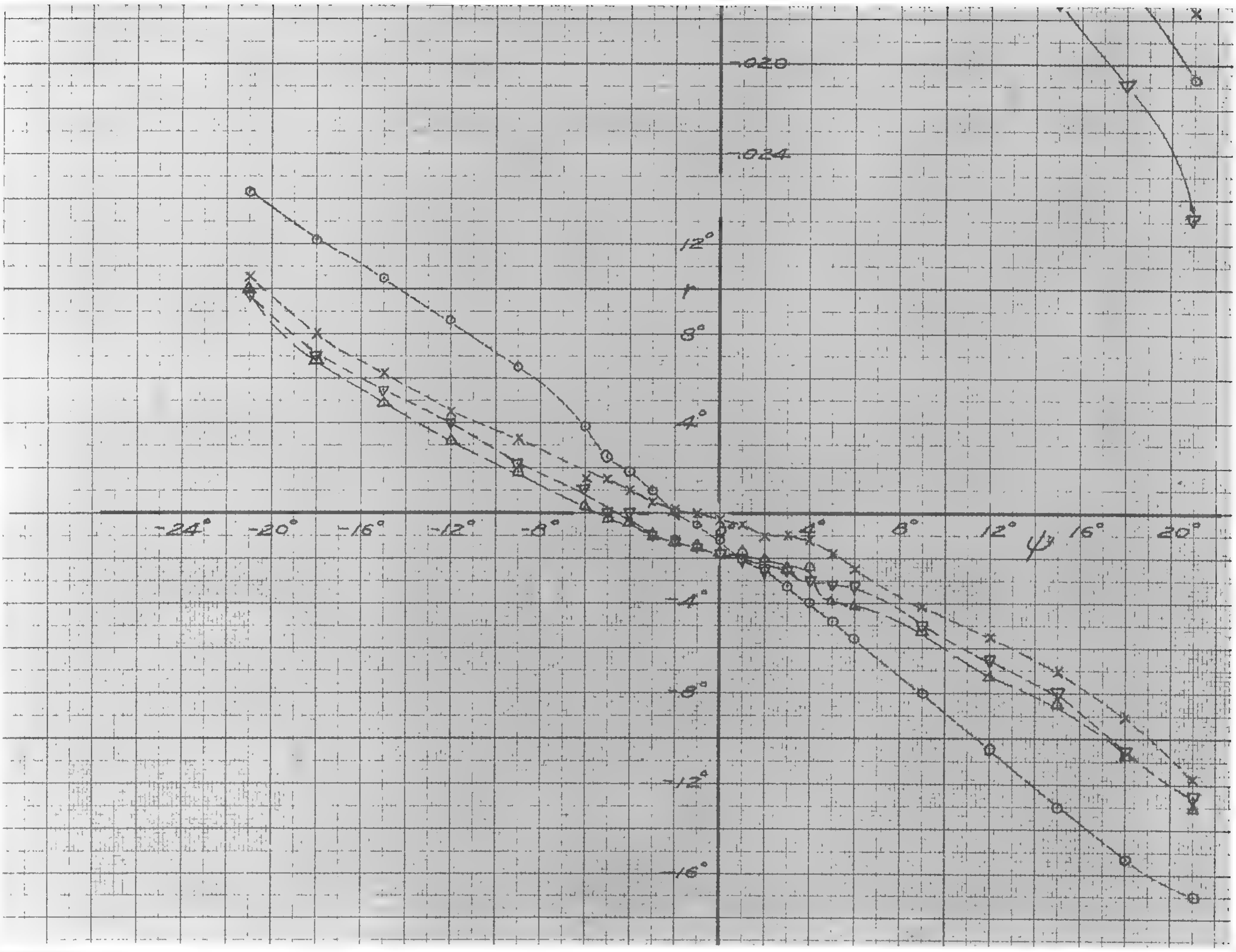
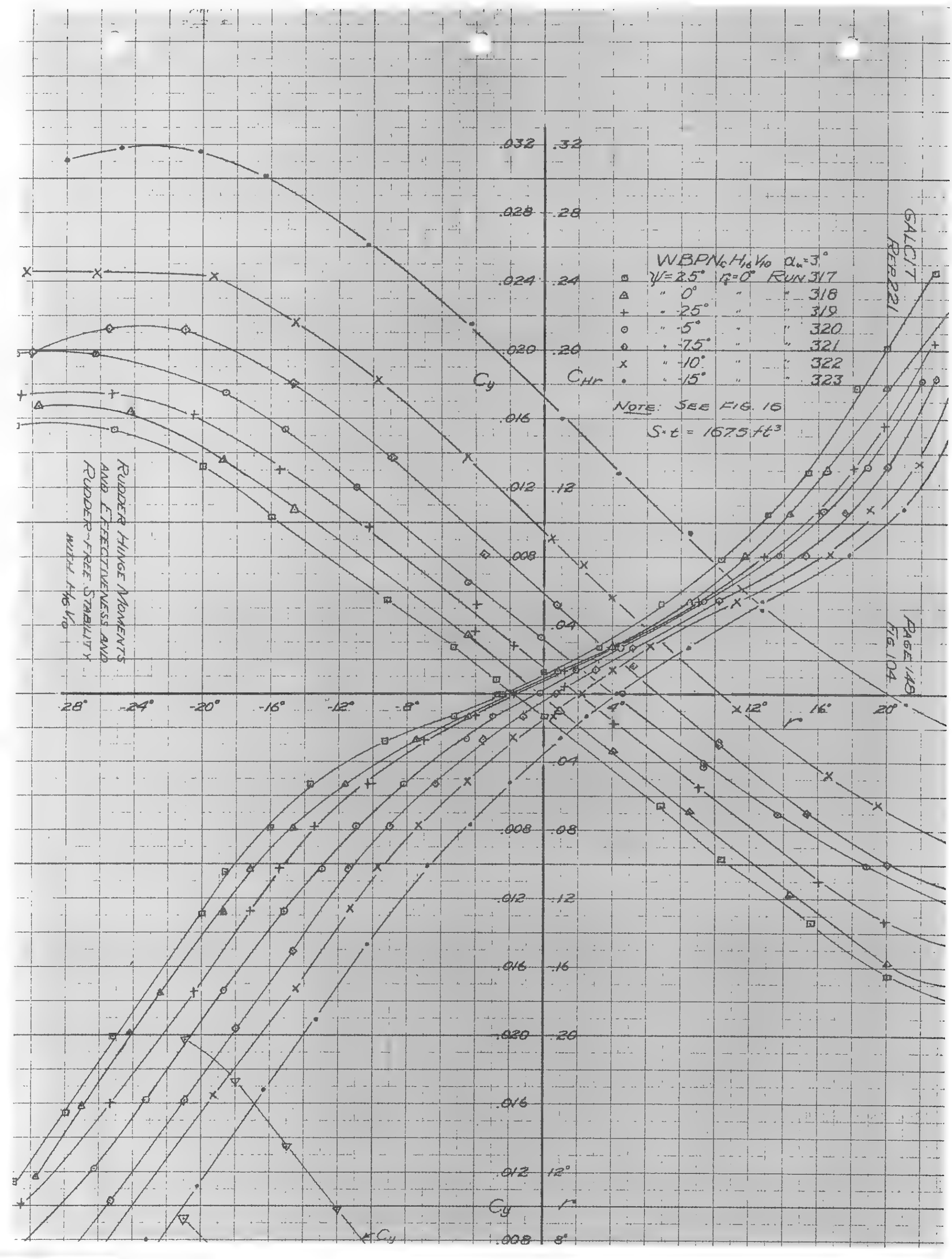
Fig 103



Directional Stability with Rudder Free
with H_{16} $V_{6,7,8}$ and with H'_{16} V_8



-24°
-20°
-16°
-12°
-8°
4°
8°
12°
16°
20°
ψ
.020
.024
12°
8°
4°
-4°
-8°
-12°
-16°


WBPN$_c$H$_{16}$V$_{10}$ α_w=3°
ψ=25° i=0° RUN 317
" 0° " 318
" -2.5° " 319
" -5° " 320
" -7.5° " 321
" -10° " 322
" -15° " 323
NOTE: SEE FIG. 16
S·t = 1675 ft³
C$_{Hr}$
C$_y$
.032 .32
.028 .28
.024 .24
.020 .20
.016
.012 .12
.008
.04
-28° -24° -20° -16° -12° -8°
4° 12° 16° 20°
.04
.008 .08
.012 .12
.016 .16
.020 .20
.016
.012 12°
C$_y$
.008 8°
+C$_y$
RUDDER HINGE MOMENTS AND EFFECTIVENESS AND RUDDER-FREE STABILITY WITH H-16
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PAGE 149 FIG. 104

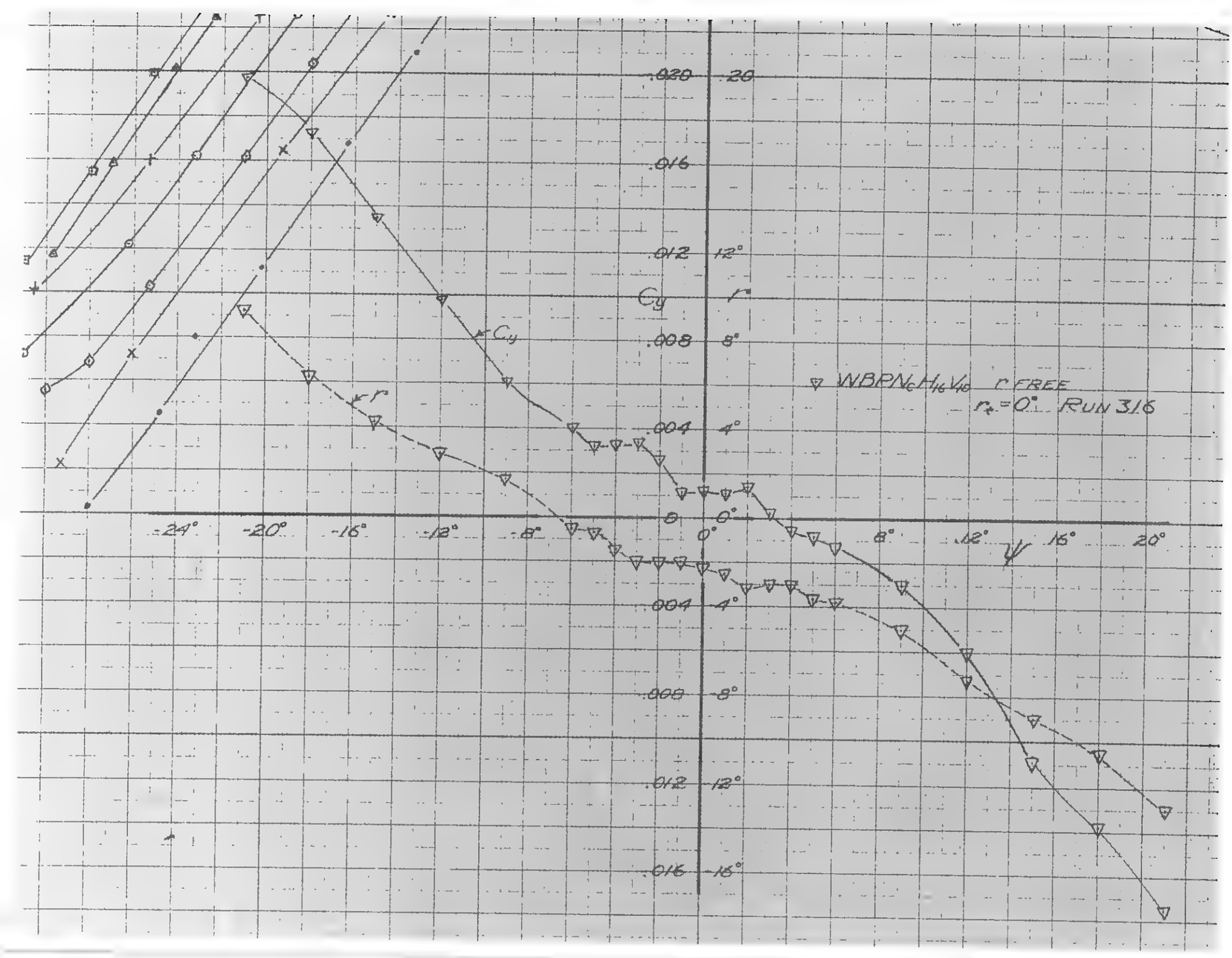
.020
.016
.012
.008
.004
0
.004
.008
.012
.016
20
12°
8°
4°
0°
4°
8°
12°
16°
20°
-24°
-20°
-16°
-12°
-8°
0°
8°
12°
16°
C_y
C_y
r
r
ψ
▽ WBPN$_6$H$_{16}$V$_{16}$ r FREE
r_+=0° RUN 316

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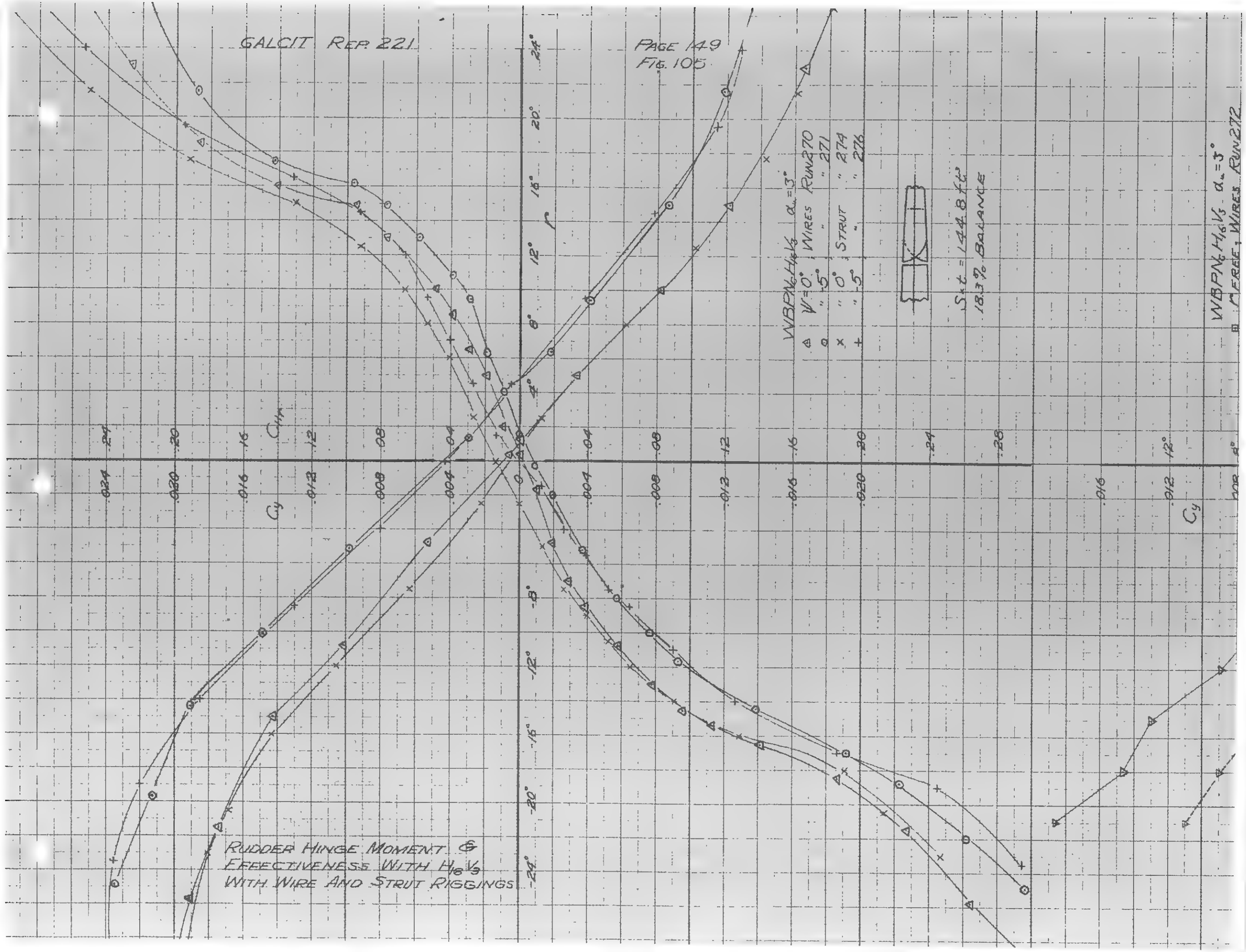
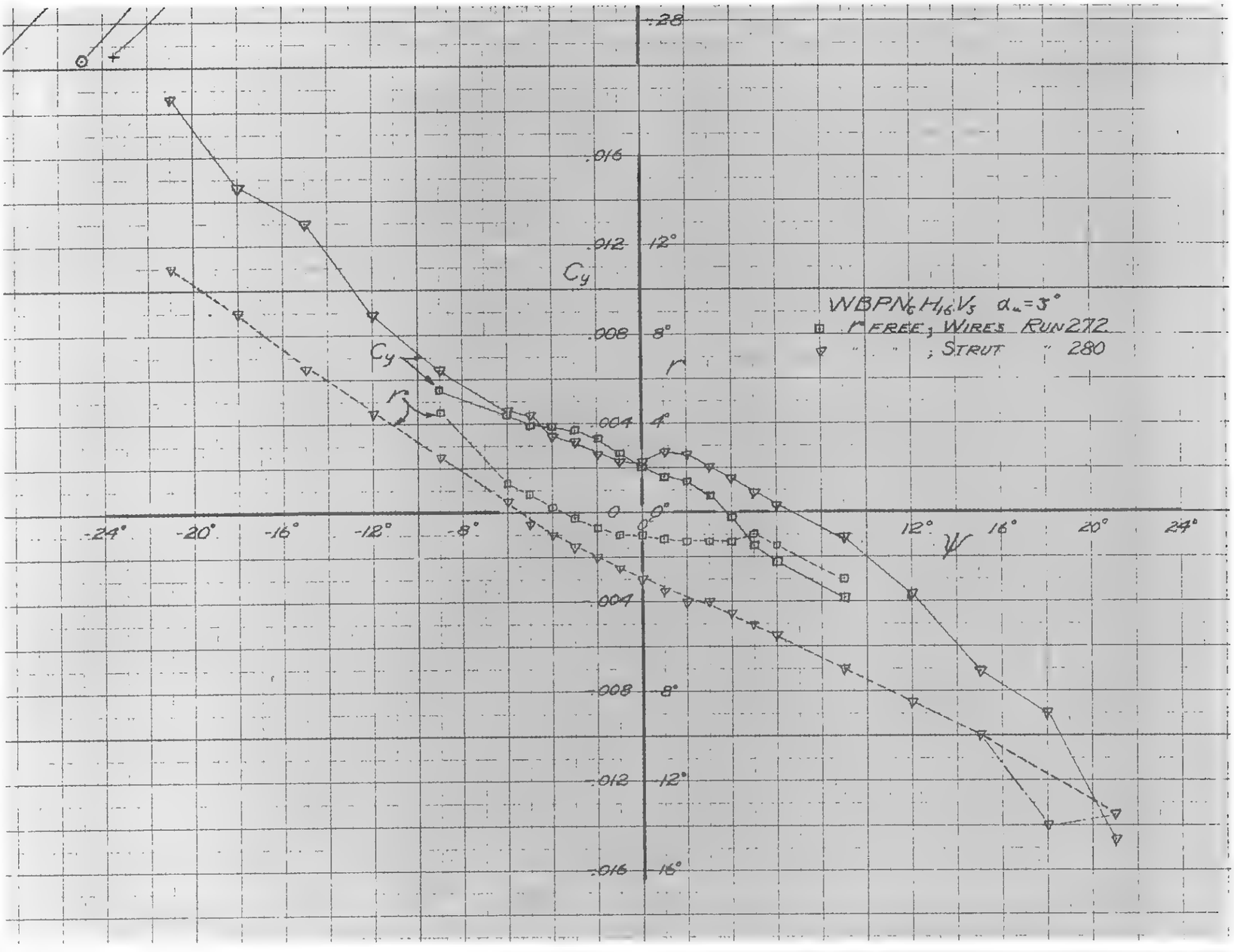
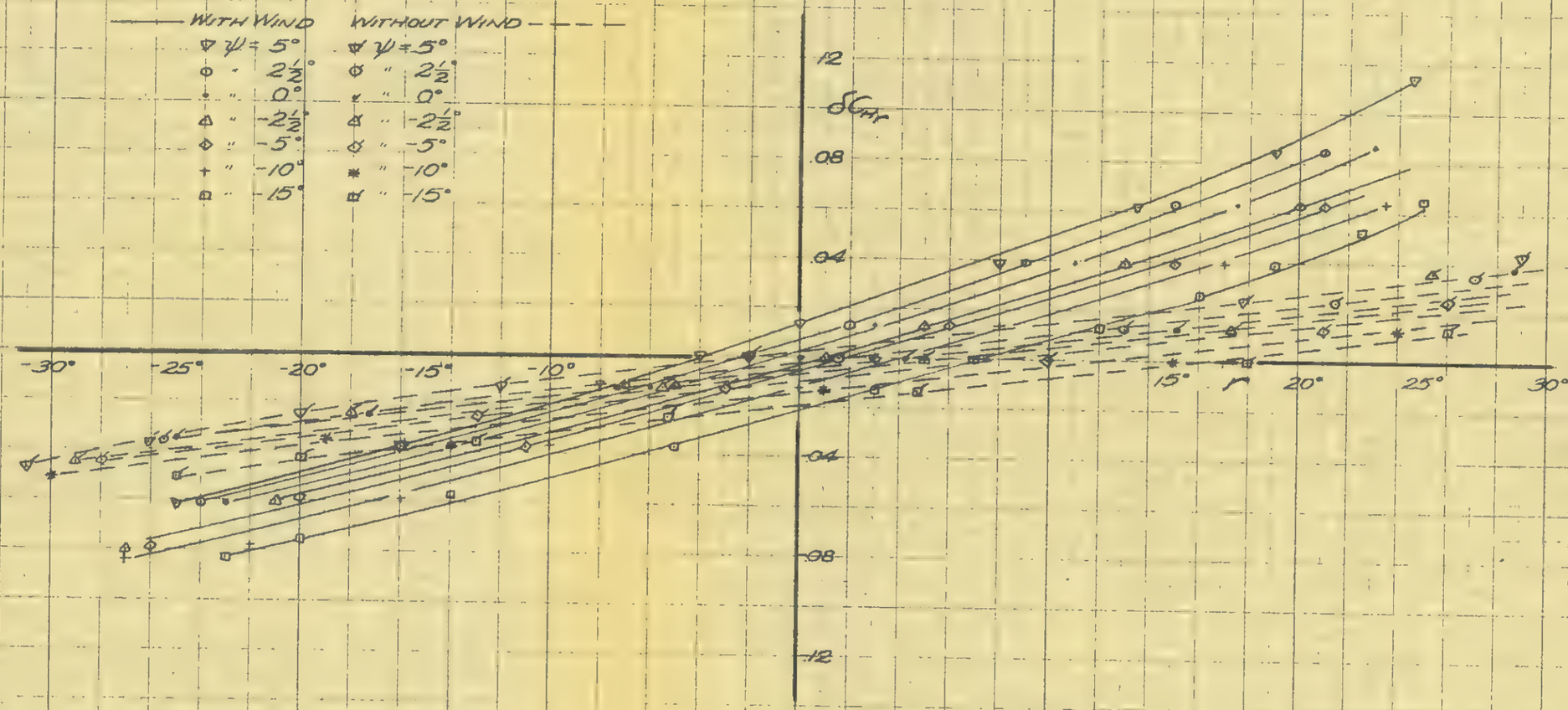
FIG. 105



RUDDER HINGE MOMENT & EFFECTIVENESS WITH H_6V_3 WITH WIRE AND STRUT RIGGINGS


WBPN6H16V3 α=3°
r FREE; WIRES RUN 272
" " ; STRUT " 280
Cy
r
-24°
-20°
-16°
-12°
-8°
0°
4°
8°
12°
16°
20°
24°
.028
.016
.012
.008
.004
.004
.008
.012
.016



HINGE MOMENT OF STRUT AND STINGS IN RUDDER HINGE MOMENT SETUP (BASED ON S_{st} = 2896 FT² - ½ FOR 2V)

NOTE: δC_{H_T} APPLICABLE PARTICULARLY TO RUNS 374 TO 384.

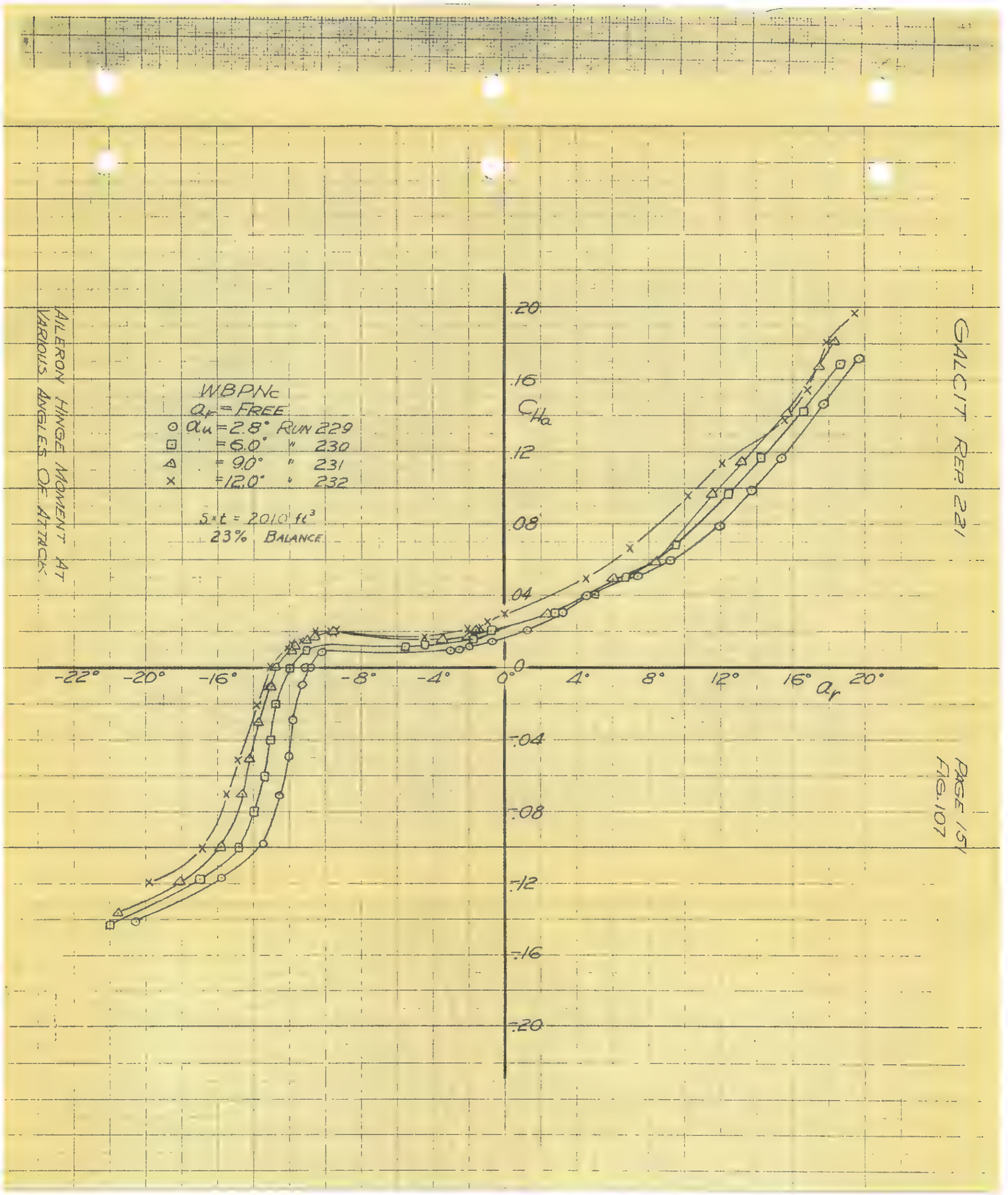

AILERON HINGE MOMENT AT VARIOUS ANGLES OF ATTACK
WBPNc
α_r = FREE
α_u = 2.8° RUN 229
= 6.0° " 230
= 9.0° " 231
= 12.0° " 232
S×t = 2010 ft³
23% BALANCE
C_{H_a}
.20
.16
.12
.08
.04
0
-.04
-.08
-.12
-.16
-.20
-22° -20° -16° -8° -4° 0° 4° 8° 12° 16° 20°
α_r
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FIG. 107

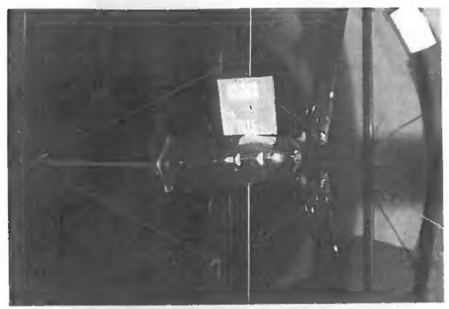

PHOTO 1.

PHOTO 2.

WBN_0PH_3V, Run 6

PHOTO 3.
H_3V_6

PHOTO 4.
H_2V_2, showing (left) bracket, b, on auxiliary fin

PHOTO 5.
$WBFN_cH_2V_2v$, showing elevator hinge-moment rigging

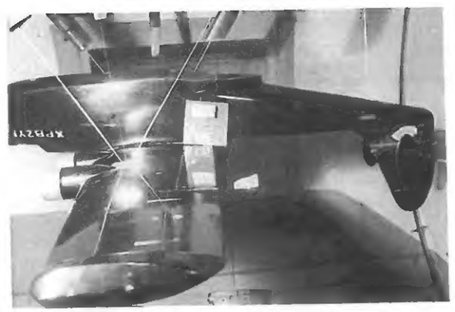

PHOTO 6.

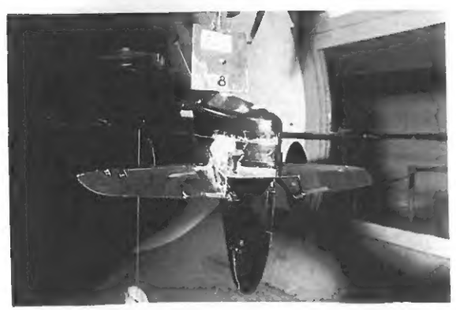

PHOTO 7.
$WBPN_cH_1V_2v$, showing setup for Run 96, elevators free, $e_t = -0.3e$

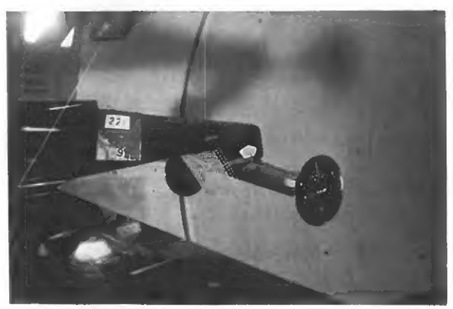

PHOTO 8.
$WBPN_cH_{16}V_3G$, Run 261

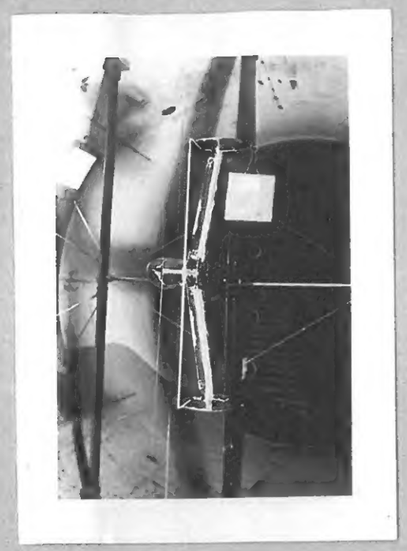

PHOTO 9.
$WBPN_6H_{16}V_3$, Run 280, showing setup for rudder hinge-moment tests with both rudders

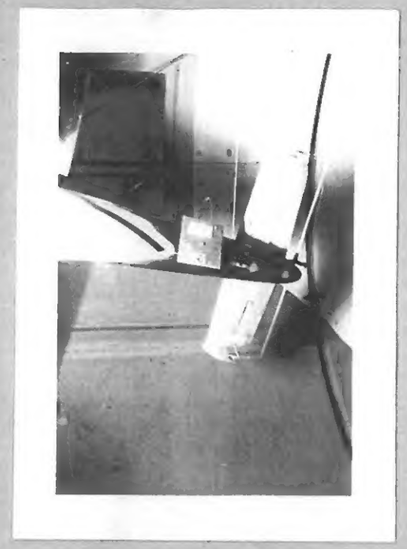

PHOTO 10.
Setup for Run 385, to determine tare hinge moment of rigging system used for twin rudders

PHOTO 11.

PHOTO 12.

WB_2P + fairing, Run 360

PHOTO 13.
Setup for Run 369: pitot tube in
position to measure wake of rigging wire

PHOTO 14.
Setup for Run 370: pitot tube in
position to measure wake of rigging wire